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OAK RIDGE Y-12 PLANT

MARTIN MARIETTA

SOURCES AND DISCHARGES OF MERCURY

IN DRAINAGE WATERS AT THE

OAK RIDGE Y-12 PLANT

R. R. Turner
G. E. Kamp
M. A. Bogle
J. Switek
R. McElhaney

June 1985

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R. R. Turner*
G. E. Kamp
M. A. Bogle*
J. Switek*
R. McElhaney

*Oak Ridge National Laboratory
Environmental Science Division

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ACKNOWLEDGEMENTS

This program has required the assistance of many more persons and organizations than would appear to be necessary based on the explicit objectives of this investigation. For example, entry into the storm sewer system on the western end of the Y-12 Plant required a modified confined space entry procedure. This involved assistance from the Industrial Safety, Industrial Hygiene, Radiation Safety, Utilities and Fire and Plant Protection Departments. The Y-12 Plant Environmental Monitoring group provided assistance in collecting the samples and coordination with the Y-12 Plant Laboratory who performed the majority of the analysis. We wish to thank all those who contributed to the success of the project.

Special appreciation for extraordinary and long term contribution to the program is extended to Lester Heidel, David Gass, II, and Jerry B. Hunt of the Health, Safety Environment and Accountability Division for their assistance in collecting samples and coordination with the Plant Laboratory. Special appreciation is extended to Ed White, Gerald Pierce and the members of the Environmental Analysis Group of the Plant Laboratory for their efforts in analyzing the samples. Special appreciation is extended to Joe Tallent of the Utilities Department for providing the program with personnel and equipment needed to enter the storm sewer system. Special appreciation is extended to Jim Crawley of the Fire Department for his assistance as a confined space entry monitor, and in particular for his initiative and ingenuity in helping us overcome the many bottlenecks that occurred in the program. Special appreciation is also extended to Marion Ferguson of the Analytical Chemistry Division for the analytical support given to this program.

The Plant Laboratory took the initiative to develop an on line mercury monitor that was put in service in January 1985. This instrument analyzes an influent and effluent sample from New Hope Pond every thirty minutes. This will allow for greatly improved analysis of the dynamics of New Hope Pond. Special appreciation is extended to Dr. E. R. Hinton, Jr., and L. K. Rawlins for their efforts in developing this instrument.

ABSTRACT

An investigation of sources and discharges of mercury in the Oak Ridge Y-12 Plant drainage water was conducted in order to effectively plan and guide remedial actions to reduce aquatic losses of mercury from the Plant. The specific objectives of the study were (1) to identify and quantify chronic and episodic sources of mercury that continue to contaminate Y-12 drainage water and (2) to determine whether New Hope Pond (NHP) is acting as a net source or a net sink for mercury emanating from the Y-12 Plant. Comprehensive surveys directed at localizing buildings and areas within the Plant which contribute significant amounts of mercury to drainage water revealed elevated mercury concentrations and discharges in the vicinity of nearly all buildings and areas where mercury was formerly used or spilled. The largest discharges were associated with Building 9204-4 (55 grams/day), 9201-5 (40 grams/day), 81-10 area (30 grams/day) and 9201-4 (25 grams/day). These discharges arise largely because residual deposits of metallic mercury located in the drainage system are being slowly solubilized or resuspended by otherwise uncontaminated groundwater and process water which flows through the drainage system en route to Upper East Fork Poplar Creek. Studies at New Hope Pond have shown that the pond traps about 50% of the mercury carried into it by Plant drainage water. Even during storm runoff from the Plant site and during Plant upsets (e.g., waterline breaks), effluent mercury concentrations at New Hope Pond have been lower than influent concentrations, attesting to the value of the pond as a trap for mercury.

EXECUTIVE SUMMARY

Small quantities of mercury continue to be mobilized and transported off site from historic deposits in buildings and the drainage system at the Y-12 Plant. Since 1977, annual average mercury concentrations in plant discharge to East Fork Poplar Creek (outflow from New Hope Pond) have ranged from 1.4 to 5.0 µg/L and annual average loadings have ranged from 11.3 kg (31 g/d) to 76.6 kg (210 g/d). The upper limits of these ranges have occurred in the period 1982-83 when sampling frequency was first greatly increased and do not necessarily imply an actual increase in mercury concentrations and loadings. Previous concentrations and loadings may have been higher. Stormflow and plant upsets (eg., waterline break in Building 9201-4) have temporarily increased mercury concentrations and loadings in NHP influent and effluent.

New Hope Pond has acted as a very effective trap for mercury transported into it by plant drainage waters. During the period July 1983 through June 1984, 16 to 74 percent of the monthly influx of mercury to the pond was trapped. The overall average trap efficiency was 50%. Trap efficiency of NHP was inversely correlated with the monthly inflow of water.

Comprehensive surveys directed at localizing buildings and areas within the plant which contribute significant amounts of mercury to drainage waters revealed elevated mercury concentrations and loadings

in the vicinity of nearly all buildings and areas where mercury was formerly used or spilled. The largest loadings were associated with Buildings 9204-4 (55 g/d), 9201-5 (40 g/d), 81-10 area (30 g/d) and 9201-4 (25 g/d). Building 9201-2 contributed an additional 10 g/d with all other areas combined yielding another 10 g/d.

Some individual sources of mercury were observed to be highly variable over short time periods (minutes to hours), apparently in response to cyclical plant operations (eg., regeneration of water treatment system at steam plant). Often both water flow as well as mercury concentration in the influent and effluent of NHP have also shown diurnal variations resulting periodically in greatly increased mercury loading. The variation in mercury loading shown by the continuous on-line monitoring of mercury concentration appears to be related to cyclical plant operations. On-line monitoring of one large storm event at NHP showed temporally corresponding discharge and mercury concentration peaks, and a consistent pattern of inflow concentrations exceeding outflow concentrations. The on-line monitoring data also revealed that diurnal variations in mercury concentration on non-storm days were often greater than the changes associated with storm flow days.

This investigation has identified the most important source areas for mercury. Areas of secondary importance, such as the area near Buildings 9103 and the 9733 complex should ultimately be investigated further. The nature of the most important sources, such as the outfall on the south side of Building 9204-4, is still not fully understood. Residual deposits of metallic mercury were observed in most of the drain lines thereby exhibiting

significant mercury loading. Thus the general hypothesis that otherwise "clean" groundwater, cooling water, and process water solubilize or resuspend mercury while flowing through the drainage system appears to be supported.

The following recommendations are suggested as a result of this study:

(1) Continue to support operation and improvement of the on-line mercury monitor on the inflow and outflow of New Hope Pond.

(2) Continue to collect weekly, or more frequent, grab samples for mercury analysis at the inflow and outflow of NHP.

(3) Establish routine monitoring sites for mercury at six locations in the drainage system.

(4) Discontinue mercury analysis of the monthly composite sample from NHP.

The following actions are recommended as a result of this study:

(1) Remove the remaining deposits of mercury and mercury-contaminated materials from the storm system (preferably by an experienced contractor) that are accessible without demolition or excavation.

(2) Isolate clean waters (once through cooling waters, condensate, etc.) from mercury-contaminated areas and piping in buildings and the storm sewer systems.

(3) Develop "clean conduits" for clean waters to get to East Fork Poplar Creek and reroute clean waters into the clean conduits.

(4) Rehabilitate the storm sewer systems in the vicinity of the former lithium isotope separation process buildings to provide "clean conduits" as well as isolate mercury-contaminated soils from the storm sewer system.

(5) After the above actions are implemented (which are intended to reduce the quantity of mercury-contaminated waters leaving buildings within the Y-12 Plant, and the Y-12 Plant itself), any residual sources of mercury-contaminated waters that were not eliminated should be collected and treated prior to discharge.

(6) Investigate means of lowering the water table around 9201-4 to prevent the spring water from entering a mercury contaminated area of the building.

(7) Investigate the feasibility of isolating in place (paving over) mercury-contaminated soils in the vicinity of the former process buildings to prevent surface run-off and reduce rain water infiltration into mercury-contaminated soils.

INTRODUCTION

1.1 Historical Background

The investigation described in this report was prompted by the need to answer the questions: "Where are significant quantities of mercury currently entering the Y-12 drainage waters, and what is the mercury loading rate (g/day) for these sources?" This information is needed in order to effectively plan and guide remedial actions to reduce the losses of mercury in Y-12 drainage waters.

Elemental mercury was used in large quantities to separate lithium isotopes at Y-12 between 1950 and 1966, with the occurrence of several significant spills of mercury during that time period (see Y-12 Report Y/EX-23, UCC-ND 1983a). By 1966, production activities requiring mercury had ceased and all but one building (9201-4) formerly containing mercury had been stripped, decontaminated, and converted to other uses. Building 9201-4 was decomissioned and mercury drained from the equipment. However, the mercury-contaminated equipment has not been removed from this building, nor have all sumps and catch basins been cleaned on a periodic basis.

Recent monitoring data for the NPDES site at New Hope Pond reveals that mercury concentrations in the discharge have ranged from <1 to 99 µg/L with X = 3 µg/L. Compared with mercury concentrations in uncontaminated streams (0.02 to 0.05 µg/L), these discharge concentrations are high. The situation is further exacerbated by the fact that the discharge from NHP essentially forms the headwaters of East Fork Poplar Creek (EFPC) and is not simply a small discharge into a mainstream river.

Prior to this study, it was assumed that recent losses of mercury in Y-12 drainage waters could be traced to Building 9201-4, which has not been stripped and decontaminated. There was also some suspicion that sediments in NHP might be acting as a source of mercury for discharge to EFPC. The NHP was extensively dredged in 1973, but surface sediments collected in May 1982 (Van Winkle et al. 1984) showed concentrations of approximately 100 μg Hg/g, with subsurface sediments up to 300 μg Hg/g. In order to effectively plan and guide any remedial actions to reduce the losses of mercury in Y-12 drainage waters, the identity and strengths of all significant sources of mercury must be determined.

1.2 Objectives

The objectives of the study are as follows:

1. Identify and quantify chronic and episodic sources of mercury that are contaminating Y-12 drainage waters.

2. Determine whether NHP is acting as a net source or a net sink for mercury emanating from the Y-12 Plant.

1.3 Approach

Identification of buildings and areas yielding mercury to drainage waters required systematic sampling of all pipes discharging water into the upper part of the creek upstream of NHP. At least 55 pipes of varying diameters provide continuous or episodic discharges of water into the creek upstream of NHP. Many of these represent storm drains which flow only during and after rainfall.

Upstream of the open ditch, the drainage system is entirely underground with access limited to manholes.

Ideally, representative sampling of all drainage waters would entail repeated sampling of the effluent from every pipe over the range of weather and plant operating conditions. Such an ambitious sampling was beyond the scope of this investigation. Instead, selected discharges were sampled repeatedly over various time scales and weather conditions to obtain an indication of variability. The number of discharge points that could be sampled was also too large to permit a truly synoptic (i.e., simultaneous) sampling of all discharges. Instead, several comprehensive surveys were conducted where up to 25 discharge points were sampled during an 8-hr period.

In addition to obtaining water samples for mercury analysis, water flow rate was measured or estimated for most discharge points to permit calculation of mercury loading rate (g/d). For correlative purposes, free chlorine, chloride, pH, electrical conductance, and temperature were also usually measured in each water sample collected.

Water sampling and flow measurement activity can be classified, based on specific objectives, into four areas.

1. Intensive sampling of selected discharge points over 24-hr to 48-hr weekday period to quantify the "within-point" variability in mercury concentration and loading.

2. Extensive sampling (one to three times) of all discharges into the
   open portion of the open ditch and of selected discharges in
   underground pipes upstream of the open ditch to localize
   significant sources of mercury.

3. Limited sampling of selected discharges occurring under storm flow
   conditions to assess the influence of high water flow rate on
   mercury loading.

4. Periodic sampling of the influent and effluent of NHP to estimate
   the trap efficiency of the pond for mercury.

1.4 Theoretical Considerations

Mercury was used at Y-12 in the metallic or elemental form.
Elemental mercury, $Hg°$, is only sparingly soluble in pure water. For
example, Kaiser and Tölg (1980) give 60 µg/L as the water solubility
of $Hg°$. This is an equilibrium value and portrays nothing about the
kinetics of dissolution which will control the concentration in a
stream of water flowing over a bed of metallic mercury. Water
overlying a pool of metallic mercury, such as in a building sump, may
achieve mercury concentrations approaching the theoretical solubility.

Metallic mercury is subject to a variety of chemical reactions,
especially oxidation, complexation, and adsorption, which can greatly alter
its solubility. At least three reactions are likely to be of special
importance in the Y-12 drainage system, (1) oxidation by hypochlorite,
(2) complexation by hydroxide and chloride ion, and (3) adsorption by

particulate matter. Hypochlorite is a by-product of one operation at Y-12 and some hypochlorite has entered drainage waters. The action of dilute hypochlorite solutions on $Hg°$ is oxidation to Hg^{2+}, which complexes strongly with hydroxy and chloroligands (Hahne and Kroontje 1973), thus greatly increasing the solubility of $Hg°$ in these solutions. Deicing salts ($NaCl$, $CaCl_2$) also increase the solubility of mercury due to the strong complexation by chloride and the increased competition for adsorption sites provided by sodium and calcium ions (Feick et al. 1972). Mercury, especially in ionic form, has a strong affinity for particulate matter. Extensive evidence exists that mercury at trace concentrations has a pronounced tendency to be adsorbed on any available surface (see review by Benes and Havlik 1979). Because neutral mercury complexes are the prevalent forms of dissolved mercury in natural waters, molecular sorption is expected to be more important than ion exchange in the association of mercury with particulate matter. However, ion exchange of mercuric cations cannot be excluded. The nature and properties of particulate matter also affect both the extent and the strength of mercury adsorption. Particle size and the content of organic matter in particulate matter are especially important. At Y-12, the presence of coal fines in some drainage waters has been thought to enhance the adsorption of mercury to particulate matter.

Overall these theoretical considerations suggest that mercury can enter Y-12 drainage water by either of two primary mechanisms;

(1) dissolution of metallic mercury trapped in sumps, catch basins, and pipes by water flowing through these structures, and

(2) erosion/resuspension of Hg-contaminated particulate matter

(soil/sediment) by surface runoff, process effluents, cooling water discharge, and groundwater infiltration. Most dissolved mercury is likely to be rapidly adsorbed on suspended particulate matter, especially fine-grained, organic-rich particulate matter.

2.0   SITES AND METHODS

2.1   Description of Sampling Locations

Figures 2.1.1 and 2.1.2 plus Table 2.1.1 display and describe the locations of all water sampling points used or considered for this investigation. No water samples were taken at a few of these locations because there was no discharge at the time of intended sampling. Water samples and data were coded as to location by one of the two labelling schemes. Pipes along the upper creek were labeled with a number representing their respective distances in meters upstream from the chain-link fence at the west end of NHP. Initially, none of these pipes were permanently labeled in this manner but can be easily relocated by reference to building numbers given in Table 2.1.1. Subsequently, the Engineering Division assigned permanent line numbers to each pipe discharging into the creek. (See Y-12 Report Y/SE-44, UCC-ND 1983b).

In the underground portion of the drainage system, water samples and data from pipes were coded first by reference to location of the culvert with respect to a nearby building (i.e., "NW9720-5" means "culvert located northwest of Building 9720-5"). Where multiple pipes entered a culvert, the coding was expanded to indicate the compass direction from which flow

Y12 DRAINAGE SYSTEM-WEST AREA
LINES AND MONITORING STATIONS

Prepared by Geographic Data Systems in Cooperation with
Health, Safety, and Environmental Affairs Division, Y12
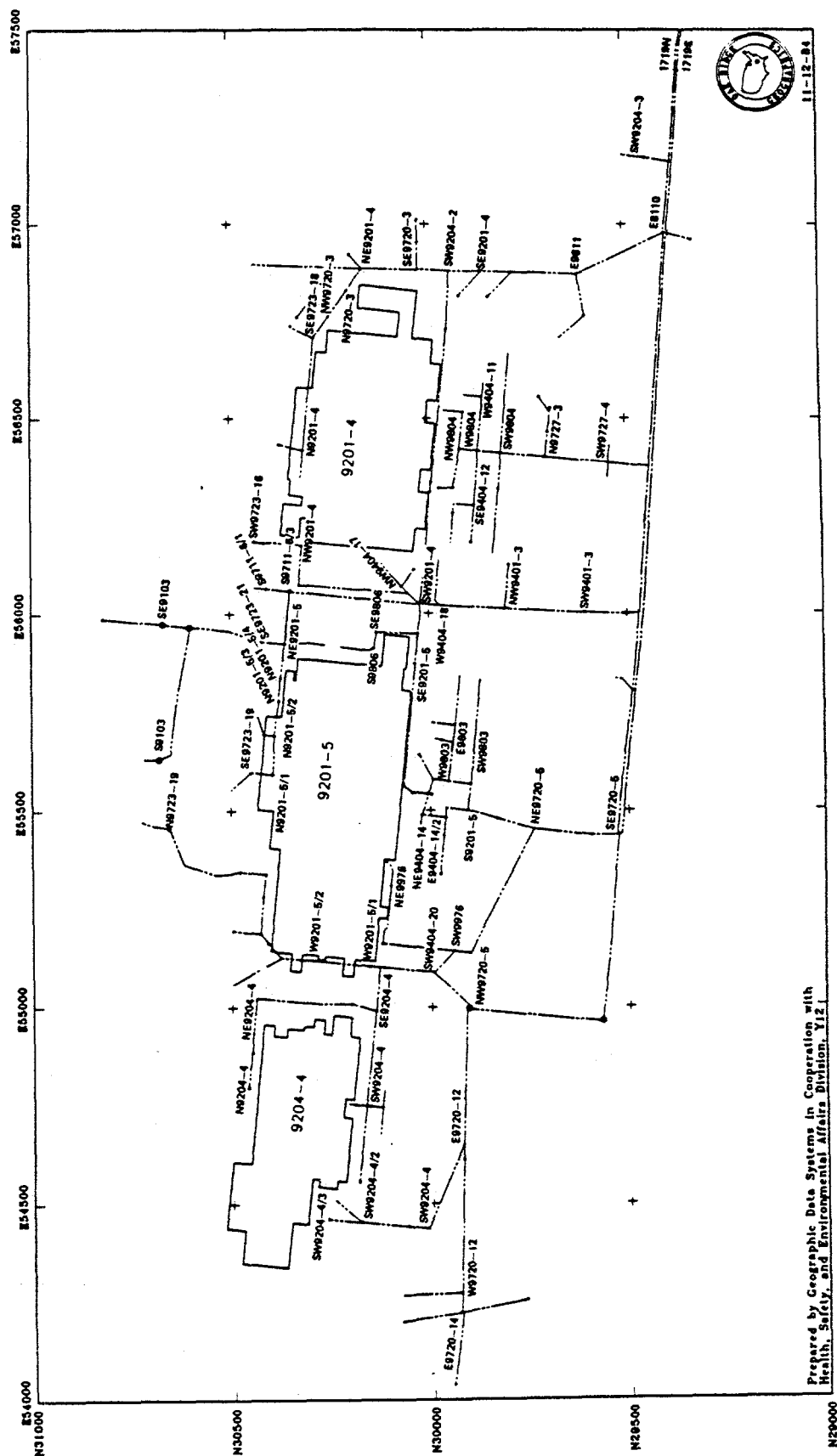
Fig. 2.1.1. Drainage lines (partial) and water sampling stations in
the western area of the Y-12 plant.

ORNL-DWG 86-1666

Y-12 DRAINAGE SYSTEM — EAST AREA DISCHARGE POINTS
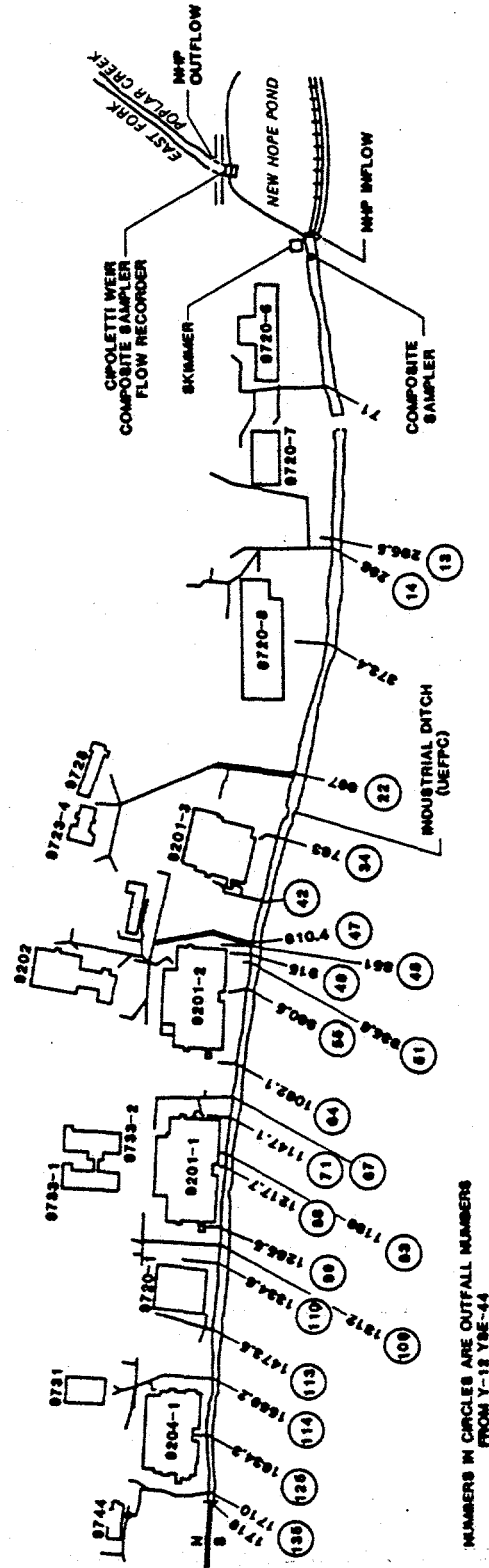
Fig. 2.1.2. Drainage lines (partial) and water sampling stations in the eastern area of the Y-12 Plant. Numbers in circles are discharge points from Y-12 Report YSE-44.

Table 2.1.1. Station codes and descriptions of water sampling locations
within the Y-12 Plant and at New Hope Pond

Station code	Line No.[a]	Flow structure	Description/location
NHP outflow	—	Stream	EFPC below NHP NPDES monitoring station
NHP inflow	—	Ditch	Inflow to NHP via dispersion channel
SKIM-NHP	5	15-in. pipe	Inflow to NHP from oil skimmer, W bank of NHP
295.5	13	10-in. pipe	Iron pipe SW of 9720-7
298	14	36-in. pipe	Concrete pipe SE of 9720-8
373.4	16	48-in. pipe	Concrete pipe S of 9720-8
377	17	18-in. pipe	Springflow on S side of ditch
430.2	18	12-in. pipe	
500	19	12-in. pipe	
518.7	—	Weir	Abandoned monitoring site with concrete weir
609.7	20	24-in. pipe	Pipe SW of 9720-8, Tag 35
667	21	48-in. pipe	Concrete pipe W of 9620-2, Tage 34
669	22	48-in. pipe	Concrete pipe W of 9620-2
712		12-in. pipe	Pipe on S side of ditch
754	33	36-in. pipe	Pipe on S side of ditch
763	34	15-in. pipe	Pipe SE of 9201-3, Tag 33
773		6-in. pipe	Pipe on S side of ditch
809.5	41	15-in. pipe	Pipe S of 9201-3, Tag 36
851	42	15-in. pipe	Pipe SW of 9201-3, Tag 32
864	45	15-in. pipe	Pipe S of 9999-3
908.1		24-in. pipe	Pipe SE of 9201-2
909.4	47	24-in. pipe	Pipe SE of 9201-2
910.4	48	24-in. pipe	Pipe SE of 9201-2
915	49	15-in. pipe	Pipe S of 9201-2

Table 2.1.1. (Continued)

Station code	Line No.[a]	Flow structure	Description/location
935.6	51	15-in. pipe	Pipe S of 9201-2
944.5		10-in. pipe	
980.5	55	15-in. pipe	Iron pipe S of 9201-2, Tag 25
1062.1			Pipe SW of 9201-2
1071.6	63	12-in. pipe	Pipe SW of 9201-2
1088.6		60-in. pipe	Ditch E bulkhead of bridge SW-9105
1113.8	67	24-in. pipe	Pipe SE of 9201-1, Tag 22
1147.1	71	12-in. pipe	Pipe SE of 9201-1
1199	83	15-in. pipe	Pipe S of 9201-1, Tag 19
1217.7	88	10-in. pipe	Pipe S of 9201-1
1220	89	12-in. pipe	Pipe S of 9201-1, Tag 19
1285.5	99	12-in. pipe	Pipe SW of 9201-1, Tag 16
1312	109	48-in. pipe	Pipe SW of 9201-1, Tag 16
1322	102	2-60-in. pipe	Ditch E bulkhead of bridge S of 9201-1
1334.6	110	15-in. pipe	Pipe SE of 9720-1
1473.5	113	18-in. pipe	Pipe SW of 9720-1
1559.2	114		Pipe SE of 9204-1
1634.3	125	201/2-in. pipe	Pipe S of 9204-1
1708.7	134	24-in. pipe	Corrugated pipe SW of 9204-1
1710.8	135	36-in. pipe	Pipe SW of 9204-1
1719N	C-2	60-in. pipe	Concrete pipe feeding N side of ditch
1719S	C-1	60-in. pipe	Concrete pipe feeding S side of ditch
SW9204-3	147	24-in. pipe	Pipe in culvert SW of 9204-3
E9811/W			Pipe in W side of culvert E of 9811

Table 2.1.1. (Continued)

Station code	Line No.[a]	Flow structure	Description/location
E9811/N	150	48-in. pipe	Pipe in N side of culvert E of 9811
SE9201-4/W		18-in. pipe	Pipe in W side of culvert SE of 9201-4
NE9201-4		90? V-notch	Weir in culvert at monitoring station
N9720-3		171/2-in. pipe	Pipe in street drain N of 9720-3
SW9727-4	160	36-in. pipe	Pipe in culvert SW of 9727-4
SW9401-3	163	60-in. pipe	Pipe in culvert SW of steam plant
SW9201-4/W		15-in. pipe	Pipe in W side of culvert SW of 9201-4
SW9201-4/N		36-in. pipe	Pipe in N side of culvert SW of 9201-4
SW9201-4/NE		15-in. pipe	Pipe in NE side of culvert SW of 9201-4
SW9201-4/E		24-in. pipe	Pipe in E side of culvert SW of 9201-4
SE9720-5/W		72-in. pipe	Pipe in W side of culvert SE of 9720-5
SE9720-5/N	169	48-in. pipe	Pipe in N side of culvert SE of 9720-5
NE9720-5/NW		48-in. pipe	Pipe in W side of culvert NE of 9720-5
NE9720-5/N		36-in. pipe	Pipe in N side of culvert NE of 9720-5
S9201-5/N		24-in. pipe	Pipe in N side of culvert S of 9201-5
S9201-5/E		36-in. pipe	Pipe in E side of culvert S of 9201-5
SW9976/N		48-in. pipe	Pipe in N side of culvert SW of 9976
SW9976/NW		48-in. pipe	Pipe in NW side of culvert NW of 9976
NW9720-5/W		72-in. pipe	Pipe in W side of culvert NW of 9720-5
NW9720-5/NE	181	48-in. pipe	Pipe in NE side of culvert NW of 9720-5
SW9204-4/NE		10-in. pipe	Pipe in NE side of culvert SW of 9204-4
SW9204-4/N		24-in. pipe	Pipe in N side of culvert SW of 9204-4

[a]Outfall number assigned by Y-12 Engineering. (See Y-12 Report YSE-44 UCC-ND 1983b)

in each pipe originated (i.e., "NW9720-5/W" means "the flow in the pipe on the west side of the culvert located northwest of 9720-5").

In the absence of a permanent and comprehensive culvert and pipe labelling system, this approach to sample identification was considered to be the least ambiguous. Figures 2.1.1 and 2.1.2 were prepared from the detailed Area Block Plan of Storm Sewers for the Y-12 Plant, and thus any future uncertainty as to sampling locations should be resolved by comparison of Figs. 2.1.1 and 2.1.2 with the block plans.

2.2 Hydrologic Measurements

Data on the flow rate of water in pipes were obtained by one of two methods: (1) the area-velocity method or (2) the volume-time method. The choice of method was largely dictated by the characteristics of each pipe. The area-velocity method consists of measuring the depth and average velocity of water in partially filled pipes. For round pipes, the cross-sectional area of flow can be readily calculated from the depth measurement. The appropriate formula is

$$A = r^2 \, \cos^{-1} \left(\frac{r - H}{r}\right) - (r - H) \sqrt{(2r \, H - H^2)}$$

where r = radius of pipe and H = depth of water.

For irregular channels (e.g., flow over the old monitoring station weir at Station 518.7) the cross-sectional area is determined by multiple depth measurements and integration. Average velocities were determined using a Marsh-McBirney Model 201 portable water current meter (inductive-type) or a Gurley Pygmy Current Meter (propeller-type). The

propeller meter was used mainly as a backup meter and occasionally to verify readings from the inductive meter. Calibration of the propeller meter was determined on March 3, 1979, by the Gulf Coast Hydroscience Center (U.S. Department of the Interior - Geological Survey Water Resources Division).

The volume-time method consists of timing the filling of a container of known volume used to catch all flow from a pipe. The method is impractical with high flow rates (more than a few liters per second) and where the entire flow cannot be directed into a container.

Flow rates determined by the area-velocity method are estimated to be accurate to within $\pm$50% or better. A lower uncertainty cannot be assured because each pipe has somewhat different characteristics that affect accuracy of depth and velocity measurements. For example, several pipes were corroded on the lower interior surface and thus were neither smooth nor cylindrical. Surface roughness introduces turbulence which decreases the precision of velocity measurement. Departure from cylindrical shape introduces error in the calculation of cross-sectional area. In addition, the presence of iron reinforcing rods in some pipes can affect accuracy of the readings on the inductive-type current meter, according to the manufacturer, in an unpredictable manner. The point is that water flow rates, and the mercury loading calculated therefrom, determined by the area-velocity method should not be considered to be highly accurate. They are 'best estimates' only.

In contrast, flow rates determined by the volume-time method should be considered to be fairly accurate ($\pm$10%). This is a direct measurement

requiring no assumptions or averaging of velocities and thus should be inherently highly accurate. However, many pipes were unsuited to application of this method due either to high volume of flow or inability to direct flow into a container. In all cases, at least three measurements were made at each location and the average time and collected volume recorded.

At two sampling locations, NHP outflow and NE9201-4, hydraulic weirs were present and could be used to accurately gage flow rate. At NHP outflow, a cipolletti weir with a 6-ft crest was used to gage flow, whereas at NE9201-4 a 90° V-notch weir was employed. In both cases, stage height readings were recorded and used with appropriate formula to calculate water flow rates. The flow rates for the weir sites should be accurate to within $\pm5\%$ but were not independently verified.

2.3 Water Sampling

All water samples collected for this investigation were of the "grab" type and thus represent instantaneous rather than composite conditions. Water samples for mercury analysis were collected in specially cleaned and prepared containers. For most of the intensive samplings (24-hr), glass volumetric flasks were used that had been baked at 550°C and prespiked with a small amount of concentrated nitric acid and K_2CrO_4. Use of glass containers pretreated with preservative represents best practice in environmental surveys for low levels of mercury in natural water (Feldman, 1974). Because of the danger of breakage, subsequent sampling employed polypropylene bottles that had been acid-washed and pretreated with nitric

acid and K_2CrO_4. A few samples were collected using both glass and plastic containers to test for differences due to container type. Samples for chloride, and other analyses not reported here, were collected in polyethylene bottles.

In most cases, only a single water sample was collected at each location per sampling time. At selected times and locations, triplicate samples were collected to obtain an estimate of sampling variability. These were collected in rapid succession (within five minutes). Samples taken at three locations in the open ditch were collected by compositing (approximately proportional to flow rate) perpendicular to the direction of flow. This was necessary to obtain a representative sample in the ditch because (1) flow rate was irregular across the direction of flow and (2) most of the pipes discharge from the north bank.

2.4 Analytical Chemistry

Field - Electrical conductance, pH, temperature, and free chloride were determined immediately (within ten minutes) after sample collection on an untreated 250-mL sample. Conductance was measured with a Barnestead Model PM-70CB conductivity bridge with dip cell (0.1 cell constant). Temperature was measured with a glass thermometer. Free chlorine was determined using the tolidene method (APHA 1975) and a Hach portable colorimeter.

Laboratory - Water samples returned to the laboratory were analyzed for chloride and total mercury. Chloride was determined by titration with mercuric nitrate (APHA 1975). Total mercury was analyzed by one of two basic procedures. Samples from the intensive surveys

(24-hr) were analyzed at ORNL by the method of Feldman (1974). In this procedure, samples are digested under reflux with dichromate, nitric, and perchloric acid. The liberated mercury (as Hg^{2+}) is reduced to the elemental state (Hg°) with stannous chloride and determined by the cold vapor atomic absorption technique (Hatch and Ott, 1968). Duplicates of ten of the samples from one of the intensive surveys were also analyzed at Y-12 using the procedure recommended by the U.S. EPA (EPA 1980). All subsequent water samples were analyzed at the Y-12 laboratory using the U.S. EPA method.

2.5 Quality Assurance

Hydrologic Measurements - The estimated accuracy and precision of flow measurements were discussed previously. In a few cases, independent measurements were possible at some locations and provide one index of data quality. For example, at Station SW9204-5/NE on December 12, 1983, the area-velocity method yielded 3.2-L/s flow rate whereas the volume-time method gave 5.9 L/s. At Station 1634.3 on December 10, 1983, the area-velocity method yielded 15 L/s whereas the volume-time method gave 9.9 L/s. The flows at both these locations were difficult to catch and time, and thus the volume-time flow rates are more uncertain than at other locations. Nonetheless, these comparisons illustrate the point that the flow measurements reported here are not highly accurate.

A second index of hydrologic data quality is provided by comparing downstream flow estimates with the sum of flows in upstream tributary pipes. Results of the extensive pipe survey on December 9, 1982, and

December 10, 1983, provided data for this kind of comparison. It should be noted, however, that these measurements were not made simultaneously. The following equations were suggested by examination of Fig. 2.1.1 and assume that pipe infiltration and exfiltration are negligible.

$$(SW9720-5/W) = (NW9720-5/W) + (NE9720-5/NE) \qquad (1)$$

$$(SE9720-5/N) = (NE9720-5/W) + (NE9720-5/N) \qquad (2)$$

$$(NE9720-5/W) = (SW9976/N) + (SW9976/NW) \qquad (3)$$

$$(1719S) = (SE9720-5/W) + (SE9720-5/N) \qquad (4)$$

$$(1719N) = (SE9401-3) + (SE9727-3) + (E9811/W) + (E9811/N) \qquad (5)$$

Inserting measured flow rates for each location and calculating relative percent deviation [100(Σtributaries – downstream)/downstream] yielded the following:

$$30 = 29.2 + 3.9 \qquad (1')$$

Relative deviation (%): +26

$$39.9 = 42 + 5.7 \qquad (2')$$

Relative deviation (%): +20

$$42 = 5.9 + 48.6 \qquad (3')$$

Relative deviation (%): +30

$$70.9 = 30 + 39.9 \qquad (4')$$

Relative deviation (%):   -1

$$113 = 22 + 13 + 53.8 + 3 \qquad (5')$$

Relative deviation (%): -19

Both 1719S and 1719N likely received additional inflows and thus the measured tributary sums were expected to be less than the flows measured at 1719S and 1719N.

Sampling and Analytical - A program of rigorous sampling and analytical quality control was followed throughout this investigation. The QA program consisted of four elements as follows:

1. Analysis of standard reference materials (SRMs) - NBS and U.S. EPA quality control samples for mercury in water were analyzed periodically to assess analytical accuracy.

2. Interlaboratory analysis - Duplicates of ten of the samples from one of the intensive surveys were analyzed by both the Y-12 Plant Laboratory and the ORNL Analytical Chemistry Division to assure comparability of results and to better define analytical accuracy. Table 2.5.1 summarizes this comparison and indicates good agreement between the laboratories.

3. Analysis of replicate samples - Within each group of samples submitted for analysis, a few (~5% of total) represented triplicate samples collected simultaneously from the same location. As indicated in Table 2.5.2, analytical plus sampling precision was usually ±10% (coefficient of variation). Two of the three values that were greater than ±10% were for samples collected in the open ditch where variability was expected to be higher.

Table 2.5.1. Interlaboratory comparison of analyses
of Y-12 drainage waters for total mercury (µg/L)

Station	Date	Time	Y-12[a]	X-10[b]
NHP outflow	10/29/82	2400	1.8	1.7
NHP inflow	10/30/82	0010	4.3	4.3
667 (21)	10/30/82	0400	0.17	0.16
910.4 (48)	10/30/82	0420	<0.10	0.07
1710.8 (135)	10/29/82	1458	0.18	0.21
1710.8 (135)	10/30/82	0445	0.14	0.17
E9811/N	10/29/82	1600	2.6	2.9
E9811/N	10/30/82	0510	2.7	3.1
NW97205/W	10/29/82	1945	1.3	1.3
NW97205/W	10/30/82	0540	1.2	1.2

[a]Analyzed by U.S. EPA method (USEPA 1980).

[b]Analyzed by method of Feldman (1974).

Table 2.5.2. Summary of total mercury analyses on replicate
water sample and coefficients of variation (100 X SD/mean)

Station	Date	Time	Replicate (μg/L)			Coefficient of variation (%)
			1	2	3	
NHP outflow	10/28/82	1344	2.7	2.4	2.5	5.9
NHP outflow	10/29/82	0600	1.8	1.9	1.9	3.1
NHP inflow	10/28/82	1400	3.0	3.1	3.1	1.9
NHP inflow	10/29/82	0610	4.7	4.5	4.4	3.4
SE9727-3	10/28/82	1530	2.2	1.9	2.1	7.4
NHP inflow	12/10/82	0950	5.2	4.9	4.3	9.5
908.5	12/10/82	1245	2.3	2.1	2.6	10.8
S9201-5/N	12/10/82	0900	5.5	5.7	5.6	1.8
NE9201-4	12/10/82	0842	0.2	<0.1	<0.1	—
518.7	11/10/82	1450	5.5	5.3	4.2	14
1088.6	11/10/82	1520	8.4	8.9	7.1	11
1322	11/10/82	1540	6.7	7.6	7.1	6.3

4. Analysis of laboratory drinking water – As part of the initial sample collections, drinking water was also collected from Building 9711 and analyzed for total mercury by the ORNL laboratory to establish analytical credibility for low-level mercury analysis. Triplicate values were 0.005, 0.005, and 0.006 µg/L. Most mercury concentrations observed in this study were greater than 0.1 µg/L, the analytical detection limit for the Y-12 laboratory.

In addition to the above QA activities, the effect of sample bottle type (glass versus plastic) on total mercury results was also determined. Table 2.5.3 summarizes this comparison and indicates no significant difference between the glass and polypropylene sample containers. Inability to bake plastic containers prior to use and to carry out the digestion in plastic has precluded use of plastic bottles where much lower mercury concentrations are being sought (Jenne and Avotins, 1975; Avotins and Jenne, 1975).

RESULTS AND DISCUSSION

3.1 New Hope Pond Effluent Monitoring

The purpose of this section is to review and evaluate recent (post 1977) monitoring data for mercury in New Hope Pond effluent in the context of the following questions: (1) How do monthly composite sample results compare with weekly grab sample results; (2) What is the average and range of mercury concentrations (µg/L) and loadings (g/day); and (3) Are there short- or long-term trends present in the monitoring data?

Table 2.5.3. Comparison of total mercury analyses on water samples collected in glass volumetric flasks versus 250-mL polypropylene bottles

Station	Date	Glass[a]		Polypropylene[b]	
		μg/L	$\overline{X} \pm SD$	μg/L	$\overline{X} \pm SD$
518.7	11/10/82	4.2, 5.5, 5.3	5.0 ± 0.7	5.5, 5.3	5.4 ± 0.1
1088.6	11/10/82	7.1, 8.4, 8.9	8.1 ± 0.9	8.0, 8.4	8.2 ± 0.2

[a]Acid-cleaned, baked at 550°C, and prespiked with concentrated HNO_3 and K_2CRO_4 to preserve mercury.

[b]Acid-cleaned and prespiked with concentrated HNO_3 and K_2CrO_4 to preserve mercury.

Between December 1977 and June 1983 both weekly grab and monthly composite water samples were collected from the effluent of New Hope Pond and analyzed for total mercury by the EPA method (UCC-ND Environmental Analysis Procedure EC-139 UCC-ND 1983). Since June 1983, daily (weekdays only) grab samples have been collected from both the influent and effluent of NHP. Grab samples have been collected in plastic bottles and returned to the Y-12 Plant labortory on the same day. If not processed on the same day as collection, the entire contents of the bottle was acidified with nitric acid in accordance with EPA recommendations. Monthly composite samples were collected using a time-proportional sampler until May 1981 and subsequently using a flow-proportional sampler. Monthly composites were actually composed of equal portions of weekly composite (NHP effluent is pumped to a 55 gallon stainless steel drum which is sampled and emptied each week).

Water level in NHP is recorded continuously on a circular chart housed in the overflow structure on the pond. The overflow structure consists of a standard cipolletti weir with a 6.0 ft crest and 2.5 ft maximum head. However, the water level recorder in use between 1977 and 1983 went off-scale at 1.63 ft and thus flows greater than 1.19 m^3/s (27 mgd) could not be recorded. Total monthly flow was calculated by numerically integrating stage height records over each month. In some cases, stage heights had to be estimated due to equipment failure or high flows (off-scale). Prior to June 1983, stage height was not recorded at the

time of sampling by the person who collected the weekly grab samples. To perform the evaluation described here, stage heights for the period prior to June 1983 were taken recently from the archived circular charts under the assumption that sampling took place at 9:00 AM on the dates of grab sampling. In nearly all cases, stage heights were not highly variable within a few hours of 9:00 AM and thus uncertainty in flow rate for these dates is low in most cases. In a few cases, stormflow was occurring and stage heights could not be accurately determined for these dates.

The analytical detection limit for both grab and composite samples processed at the Y-12 Plant Laboratory has been 1 µg/L until recently and many NHP effluent samples were reported to contain less than 1 µg/L. For the purpose of numerical evaluation, these 'less than' values have been assumed to be equal to one-half of the 'less than' value, or 0.5 µg/L.

Tables 3.1.1 and 3.1.2 give the weekly and monthly data, respectively, for the period December 1977 through July 1984. An important question concerns which of these data sets should be used to calcuate mercury discharges from the Y-12 Plant. As discussed subsequently, one data set leads to higher calculated discharges than the other data set. To compare the weekly data with the monthly data, flow-weighted average mercury concentrations for each month were calculated from the weekly data. Flow-weighted averages ($\overline{c_w}$) were calculated as

$$\overline{c_w} = \frac{\sum\limits_{i=1}^{n} Q_i c_i}{\sum\limits_{i=1}^{n} Q_i}$$

where Q_i = flow rate at time of sampling, C_i = mercury

Table 3.1.1. Weekly grab sample data for mercury in New Hope Pond
effluent for December 1977–July 1984

Date	Discharge (m³/s)	Discharge (mgd)	Hg (µg/L)	Hg Loading (g/d)
06DEC77	0.15	3.51	4.0	53.2
07DEC77	0.18	4.05	3.0	46.0
13DEC77	0.09	2.06	3.0	23.4
13DEC77	0.09	2.06	3.0	23.4
14DEC77	0.27	6.07	3.0	68.9
06JAN78	0.27	6.19	3.0	70.4
09JAN78	.	.	3.0	.
10JAN78	.	.	3.0	.
16JAN78	0.13	2.90	4.0	43.9
24JAN78	0.14	3.30	3.0	37.5
30JAN78	0.14	3.30	3.0	37.5
10FEB78	0.13	3.00	2.0	22.7
12FEB78	0.10	2.33	3.0	26.4
13FEB78	0.24	5.45	4.0	82.5
16FEB78	0.12	2.70	4.0	40.9
16FEB78	0.12	2.70	3.0	30.7
17FEB78	0.11	2.51	3.0	28.5
17FEB78	0.11	2.51	3.0	28.5
27FEB78	0.11	2.51	2.0	19.0
06MAR78	0.12	2.80	2.0	21.2
13MAR78	.	.	1.0	.
20MAR78	0.13	2.90	1.0	11.0
27MAR78	0.14	3.20	1.0	12.1
05APR78	0.29	6.58	2.0	49.8
11APR78	0.27	6.07	2.0	45.9
17APR78	0.25	5.82	2.0	44.0
24APR78	0.26	5.94	3.0	67.5
01MAY78	0.35	7.92	2.0	60.0
08MAY78	0.29	6.71	1.0	25.4
15MAY78	0.31	7.11	1.0	26.9
22MAY78	0.27	6.19	0.5	11.7
05JUN78	0.27	6.19	1.0	23.5
12JUN78	0.27	6.07	1.0	23.0
19JUN78	0.27	6.07	1.0	23.0
26JUN78	0.30	6.84	1.0	25.9
05JUL78	0.25	5.82	1.0	22.0
10JUL78	0.25	5.82	0.5	11.0
17JUL78	0.25	5.82	0.5	11.0
24JUL78	0.24	5.57	1.0	21.1
31JUL78	0.24	5.45	0.5	10.3
07AUG78	0.26	5.94	1.0	22.5
14AUG78	>1.19	>27.05	1.0	>102.4
21AUG78	0.29	6.58	2.0	49.8
28AUG78	0.28	6.32	2.0	47.9

Table 3.1.1. (Continued)

Date	Discharge (m³/s)	Discharge (mgd)	Hg (μg/L)	Hg Loading (g/d)
05SEP78	0.27	6.07	0.5	11.5
11SEP78	0.46	10.53	0.5	19.9
18SEP78	0.27	6.19	0.5	11.7
25SEP78	0.25	5.82	0.5	11.0
02OCT78	0.26	5.94	0.5	11.2
16OCT78	0.23	5.33	0.5	10.1
23OCT78	0.27	6.07	0.5	11.5
02NOV78	0.22	5.09	0.5	9.6
06NOV78	0.24	5.45	0.5	10.3
13NOV78	0.24	5.57	0.5	10.5
20NOV78	0.26	5.94	2.0	45.0
27NOV78	0.37	8.48	2.0	64.2
04DEC78	0.80	18.25	1.0	69.1
11DEC78	0.32	7.24	1.0	27.4
18DEC78	0.26	5.94	2.0	45.0
27DEC78	0.27	6.19	1.0	23.5
03JAN79	0.35	8.06	2.0	61.0
08JAN79	0.50	11.46	3.0	130.1
15JAN79	0.28	6.32	1.0	23.9
22JAN79	0.40	9.05	2.0	68.5
29JAN79	0.29	6.71	2.0	50.8
05FEB79	0.27	6.19	1.0	23.5
12FEB79	0.27	6.07	2.0	45.9
20FEB79	0.28	6.45	3.0	73.3
26FEB79	0.55	12.57	1.0	47.6
05MAR79	0.42	9.64	2.0	73.0
12MAR79	0.29	6.71	2.0	50.8
19MAR79	0.27	6.07	2.0	45.9
26MAR79	0.28	6.45	3.0	73.3
02APR79	0.76	17.34	3.0	197.0
09APR79	0.45	10.23	1.0	38.7
16APR79	0.31	7.11	1.0	26.9
23APR79	0.25	5.82	0.5	11.0
30APR79	0.24	5.57	2.0	42.2
07MAY79	0.24	5.57	2.0	42.2
14MAY79	0.25	5.82	1.0	22.0
21MAY79	0.29	6.71	0.5	12.7
29MAY79	0.28	6.32	1.0	23.9
04JUN79	0.54	12.25	1.0	46.4
11JUN79	0.28	6.45	1.0	24.4
18JUN79	0.27	6.07	2.0	45.9
25JUN79	0.25	5.82	1.0	22.0

Table 3.1.1 (Continued)

Date	Discharge (m^3/s)	Discharge (mgd)	Hg (μg/L)	Hg Loading (g/d)
02JUL79	0.29	6.58	2.0	49.8
10JUL79	0.47	10.69	1.0	40.5
16JUL79	0.30	6.84	1.0	25.9
23JUL79	0.37	8.48	2.0	64.2
30JUL79	0.35	8.06	2.0	61.0
06AUG79	0.29	6.71	2.0	50.8
13AUG79	0.31	7.11	2.0	53.8
20AUG79	0.28	6.45	2.0	48.8
27AUG79	0.30	6.84	0.5	13.0
04SEP79	0.31	6.97	0.5	13.2
10SEP79	0.28	6.45	1.0	24.4
17SEP79	0.27	6.19	2.0	46.9
24SEP79	0.25	5.82	1.0	22.0
01OCT79	0.28	6.45	0.5	12.2
08OCT79	0.27	6.19	6.0	140.7
15OCT79	0.29	6.71	2.0	50.8
22OCT79	0.28	6.45	1.0	24.4
29OCT79	0.28	6.45	0.5	12.2
05NOV79	0.29	6.58	1.0	24.9
12NOV79	0.34	7.78	2.0	58.9
19NOV79	0.28	6.45	1.0	24.4
26NOV79	0.40	9.20	0.5	17.4
03DEC79	0.28	6.45	2.0	48.8
10DEC79	0.28	6.32	1.0	23.9
17DEC79	0.28	6.45	2.0	48.8
26DEC79	0.31	7.11	2.0	53.8
31DEC79	0.30	6.84	2.0	51.8
07JAN80	0.39	8.91	2.0	67.5
14JAN80	0.40	9.20	1.0	34.8
28JAN80	0.28	6.45	2.0	48.8
04FEB80	0.35	7.92	2.0	60.0
11FEB80	0.29	6.71	3.0	76.2
19FEB80	0.28	6.45	6.0	146.5
25FEB80	0.28	6.32	2.0	47.9
03MAR80	0.29	6.71	3.0	76.2
10MAR80	0.32	7.24	2.0	54.8
17MAR80	.	.	1.0	.
24MAR80	.	.	0.5	.
31MAR80	0.37	8.48	2.0	64.2
07APR80	0.32	7.38	2.0	55.8
14APR80	0.47	10.69	3.0	121.4
21APR80	0.34	7.78	1.0	29.5
28APR80	0.34	7.78	1.0	29.5
05MAY80	0.31	7.11	2.0	53.8
12MAY80	0.34	7.78	2.0	58.9
19MAY80	0.47	10.69	2.0	80.9
29MAY80	.	.	2.0	.

Table 3.1.1 (Continued)

Date	Discharge (m^3/s)	Discharge (mgd)	Hg (µg/L)	Hg Loading (g/d)
02JUN80	0.42	9.49	2.0	71.8
09JUN80	0.29	6.58	1.0	24.9
16JUN80	0.28	6.32	3.0	71.8
23JUN80	0.27	6.19	3.0	70.4
30JUN80	0.28	6.32	2.0	47.9
09JUL80	0.29	6.71	1.0	25.4
14JUL80	0.32	7.38	1.0	27.9
23JUL80	0.31	7.11	2.0	53.8
18AUG80	0.32	7.24	1.0	27.4
25AUG80	0.31	7.11	1.0	26.9
02SEP80	0.28	6.45	1.0	24.4
09SEP80	0.28	6.45	1.0	24.4
16SEP80	0.29	6.58	2.0	49.8
22SEP80	0.31	7.11	1.0	26.9
30SEP80	0.34	7.78	0.5	14.7
07OCT80	0.36	8.20	0.5	15.5
13OCT80	0.37	8.48	2.0	64.2
21OCT80	0.39	8.91	2.0	67.5
28OCT80	0.40	9.20	2.0	69.6
04NOV80	0.42	9.64	2.0	73.0
12NOV80	0.34	7.65	2.0	57.9
08DEC80	0.34	7.78	2.0	58.9
22DEC80	0.34	7.65	1.0	28.9
31DEC80	0.27	6.07	2.0	45.9
05JAN81	0.29	6.58	3.0	74.7
13JAN81	0.32	7.24	3.0	82.2
19JAN81	0.31	7.11	4.0	107.6
28JAN81	0.32	7.38	0.5	14.0
02FEB81	0.56	12.73	3.0	144.6
09FEB81	0.32	7.38	3.0	83.8
17FEB81	0.32	7.24	2.0	54.8
23FEB81	0.37	8.48	2.0	64.2
03MAR81	0.28	6.45	1.0	24.4
09MAR81	0.28	6.32	2.0	47.9
16MAR81	0.31	7.11	2.0	53.8
23MAR81	0.34	7.65	2.0	57.9
30MAR81	0.78	17.88	1.0	67.7
08APR81	0.37	8.34	2.0	63.1
13APR81	0.34	7.78	2.0	58.9
20APR81	0.64	14.55	1.0	55.1
29APR81	0.42	9.49	2.0	71.8
05MAY81	0.31	6.97	4.0	105.6
13MAY81	0.31	6.97	0.5	13.2
19MAY81	0.39	8.91	1.0	33.7
27MAY81	0.31	7.11	0.5	13.5

Table 3.1.1 (Continued)

Date	Discharge (m³/s)	Discharge (mgd)	Hg (µg/L)	Hg Loading (g/d)
03JUN81	0.36	8.20	0.5	15.5
10JUN81	0.32	7.38	0.5	14.0
15JUN81	0.31	7.11	0.5	13.5
22JUN81	0.37	8.34	1.0	31.6
01JUL81	0.27	6.19	1.0	23.5
08JUL81	0.33	7.51	1.0	28.4
14JUL81	0.32	7.38	1.0	27.9
21JUL81	0.30	6.84	1.0	25.9
28JUL81	0.31	7.11	0.5	13.5
05AUG81	0.25	5.69	1.0	21.6
10AUG81	0.25	5.82	2.0	44.0
17AUG81	0.25	5.82	0.5	11.0
25AUG81	0.26	5.94	2.0	45.0
01SEP81	0.29	6.58	1.0	24.9
08SEP81	0.28	6.45	2.0	48.8
14SEP81	0.28	6.45	2.0	48.8
21SEP81	0.28	6.32	2.0	47.9
28SEP81	0.27	6.07	1.0	23.0
05OCT81	0.24	5.57	0.5	10.5
13OCT81	0.24	5.57	0.5	10.5
20OCT81	0.25	5.69	1.0	21.6
26OCT81	0.61	13.88	0.5	26.3
02NOV81	0.25	5.69	0.5	10.8
10NOV81	0.27	6.07	0.5	11.5
16NOV81	0.25	5.82	0.5	11.0
30NOV81	0.26	5.94	1.0	22.5
07DEC81	0.26	5.94	1.0	22.5
15DEC81	0.26	5.94	1.0	22.5
22DEC81	0.80	18.25	1.0	69.1
29DEC81	0.27	6.07	0.5	11.5
04JAN82	0.72	16.45	2.0	124.6
12JAN82	0.29	6.58	3.0	74.7
18JAN82	0.29	6.71	3.0	76.2
25JAN82	0.35	8.06	2.0	61.0
02FEB82	0.29	6.71	2.0	50.8
08FEB82	0.32	7.38	2.0	55.8
16FEB82	.	.	2.0	.
22FEB82	.	.	2.0	.
02MAR82	0.32	7.24	2.0	54.8
08MAR82	0.42	9.64	1.0	36.5
15MAR82	>1.19	>27.05	40.0	>4095.8
22MAR82	0.46	10.53	1.0	39.9
29MAR82	0.32	7.38	2.0	55.8

Table 3.1.1 (Continued)

Date	Discharge (m^3/s)	Discharge (mgd)	Hg ($\mu g/L$)	Hg Loading (g/d)
05APR82	0.32	7.38	1.0	27.9
12APR82	0.34	7.78	2.0	58.9
20APR82	0.33	7.51	0.5	14.2
26APR82	0.40	9.05	0.5	17.1
03MAY82	0.31	7.11	0.5	13.5
10MAY82	0.31	7.11	0.5	13.5
17MAY82	0.31	7.11	1.0	26.9
24MAY82	0.32	7.38	1.0	27.9
02JUN82	0.32	7.38	1.0	27.9
07JUN82	0.34	7.65	1.0	28.9
15JUN82	0.33	7.51	0.5	14.2
22JUN82	0.40	9.05	0.5	17.1
28JUN82	0.35	7.92	1.0	30.0
06JUL82	0.35	8.06	1.0	30.5
12JUL82	0.37	8.48	2.0	64.2
19JUL82	0.31	7.11	3.0	80.7
26JUL82	0.34	7.78	2.0	58.9
02AUG82	0.35	8.06	2.0	61.0
09AUG82	>1.19	>27.05	2.0	>204.8
16AUG82	0.40	9.05	1.0	34.3
25AUG82	.	.	1.0	.
02SEP82	>1.19	>27.05	3.0	>307.2
07SEP82	0.34	7.78	1.0	29.5
13SEP82	0.35	7.92	2.0	60.0
20SEP82	0.35	8.06	2.0	61.0
27SEP82	0.34	7.78	2.0	58.9
04OCT82	0.34	7.78	3.0	88.4
11OCT82	0.34	7.65	3.0	86.8
18OCT82	0.33	7.51	2.0	56.9
25OCT82	0.34	7.78	1.0	29.5
01NOV82	0.35	7.92	1.0	30.0
08NOV82	0.35	8.06	2.0	61.0
15NOV82	0.36	8.20	2.0	62.1
22NOV82	0.65	14.72	1.0	55.7
29NOV82	0.50	11.46	2.0	86.8
06DEC82	0.45	10.38	1.0	39.3
13DEC82	0.42	9.49	1.0	35.9
20DEC82	0.39	8.91	0.5	16.9
27DEC82	0.38	8.76	0.5	16.6
03JAN83	0.37	8.48	0.5	16.1
10JAN83	0.36	8.20	2.0	62.1
17JAN83	0.31	7.11	1.0	26.9
24JAN83	0.35	7.92	1.0	30.0
31JAN83	0.34	7.78	0.5	14.7

Table 3.1.1 (Continued)

Date	Discharge (m^3/s)	Discharge (mgd)	Hg (μg/L)	Hg Loading (g/d)
07FEB83	0.45	10.38	0.5	19.7
15FEB83	0.40	9.20	0.5	17.4
22FEB83	0.41	9.34	0.5	17.7
28FEB83	0.37	8.48	0.5	16.1
07MAR83	0.42	9.49	0.5	18.0
14MAR83	0.38	8.76	0.5	16.6
21MAR83	0.35	8.06	0.5	15.3
28MAR83	0.36	8.20	0.5	15.5
11APR83	0.44	9.93	1.0	37.6
18APR83	0.65	14.72	0.5	27.9
22JUN83	0.33	7.51	5.0	142.2
22JUN83	0.33	7.51	8.0	227.5
22JUN83	0.44	10.08	7.0	267.2
22JUN83	0.46	10.53	99.0	3948.3
22JUN83	0.42	9.64	79.0	2882.0
22JUN83	0.41	9.34	64.0	2263.7
22JUN83	0.40	9.20	37.0	1288.3
22JUN83	0.40	9.20	27.0	940.1
22JUN83	0.38	8.76	31.0	1028.7
22JUN83	0.38	8.76	27.0	895.9
22JUN83	0.37	8.48	33.0	1059.5
23JUN83	0.32	7.38	8.0	223.4
23JUN83	0.32	7.38	7.0	195.5
23JUN83	0.36	8.20	12.0	372.5
23JUN83	0.36	8.20	13.0	403.5
24JUN83	0.34	7.78	20.0	589.4
24JUN83	0.34	7.78	6.0	176.8
24JUN83	0.34	7.78	7.0	206.3
24JUN83	0.34	7.78	7.0	206.3
25JUN83	0.33	7.51	4.0	113.7
25JUN83	0.33	7.51	5.0	142.2
26JUN83	.	.	7.0	.
26JUN83	.	.	6.0	.
27JUN83	0.34	7.78	7.0	206.3
27JUN83	0.34	7.78	5.0	147.3
28JUN83	0.35	8.06	5.0	152.6
28JUN83	0.37	8.48	6.0	192.6
29JUN83	0.34	7.78	5.0	147.3
30JUN83	0.35	8.06	6.0	183.1
30JUN83	0.38	8.76	6.0	199.1
30JUN83	.	.	4.0	.

Table 3.1.1 (Continued)

Date	Discharge (m^3/s)	Discharge (mgd)	Hg (µg/L)	Hg Loading (g/d)
05JUL83	0.37	8.48	7.0	224.7
05JUL83	0.38	8.62	10.0	326.4
06JUL83	0.32	7.24	4.0	109.7
06JUL83	0.34	7.78	7.0	206.3
07JUL83	0.33	7.51	3.0	85.3
07JUL83	0.35	8.06	6.0	183.1
08JUL83	0.34	7.78	4.0	117.9
08JUL83	0.35	8.06	5.0	152.6
11JUL83	0.34	7.78	12.0	353.6
11JUL83	0.37	8.34	9.0	284.2
12JUL83	0.34	7.78	4.0	117.9
12JUL83	0.35	7.92	5.0	150.0
13JUL83	0.35	8.06	4.0	122.1
14JUL83	0.35	7.92	4.0	120.0
15JUL83	0.35	8.06	3.0	91.5
18JUL83	0.35	7.92	3.0	90.0
19JUL83	0.35	7.92	2.0	60.0
19JUL83	.	.	3.0	.
20JUL83	0.34	7.78	2.0	58.9
21JUL83	0.40	9.20	2.0	69.6
22JUL83	0.37	8.48	2.0	64.2
25JUL83	.	.	5.0	.
25JUL83	0.38	8.62	5.0	163.2
26JUL83	0.35	7.92	5.0	150.0
27JUL83	0.35	8.06	2.0	61.0
28JUL83	0.35	7.92	2.0	60.0
29JUL83	0.34	7.78	2.0	58.9
01AUG83	.	.	3.0	.
01AUG83	0.42	9.49	4.0	143.7
02AUG83	0.35	7.92	2.0	60.0
03AUG83	0.35	7.92	2.0	60.0
04AUG83	0.36	8.20	1.0	31.0
05AUG83	0.35	8.06	1.0	30.5
07AUG83	.	.	2.0	.
08AUG83	0.32	7.38	7.0	195.5
08AUG83	.	.	4.0	.
09AUG83	0.34	7.78	1.0	29.5
10AUG83	0.35	7.92	2.0	60.0
11AUG83	0.33	7.51	2.0	56.9
12AUG83	0.34	7.78	0.5	14.7
15AUG83	.	.	0.5	.
15AUG83	0.34	7.65	1.0	28.9
16AUG83	0.34	7.78	1.0	29.5
17AUG83	0.32	7.24	2.0	54.8
18AUG83	0.34	7.65	2.0	57.9

Table 3.1.1 (Continued)

Date	Discharge (m^3/s)	Discharge (mgd)	Hg (µg/L)	Hg Loading (g/d)
19AUG83	0.34	7.78	2.0	58.9
22AUG83	0.35	8.06	1.0	30.5
23AUG83	0.34	7.78	1.0	29.5
24AUG83	0.35	7.92	2.0	60.0
25AUG83	0.35	7.92	2.0	60.0
26AUG83	0.34	7.78	1.0	29.5
29AUG83	0.34	7.78	3.0	88.4
30AUG83	0.32	7.24	1.0	27.4
31AUG83	0.33	7.51	1.0	28.4
01SEP83	0.34	7.78	2.0	58.9
02SEP83	0.34	7.65	2.0	57.9
06SEP83	0.34	7.65	2.0	57.9
07SEP83	0.33	7.51	2.0	56.9
08SEP83	0.32	7.38	1.0	27.9
09SEP83	0.34	7.78	1.0	29.5
12SEP83	0.32	7.24	2.0	54.8
13SEP83	0.32	7.24	2.0	54.8
14SEP83	.	.	2.0	.
15SEP83	0.31	7.11	2.0	53.8
16SEP83	0.31	7.11	1.0	26.9
19SEP83	0.31	7.11	1.0	26.9
20SEP83	0.31	7.11	0.5	13.5
21SEP83	0.54	12.41	1.0	47.0
22SEP83	0.31	7.11	1.0	26.9
23SEP83	0.32	7.24	1.0	27.4
26SEP83	0.32	7.24	2.0	54.8
27SEP83	0.32	7.24	0.5	13.7
28SEP83	0.33	7.51	1.0	28.4
29SEP83	0.33	7.51	0.5	14.2
30SEP83	0.33	7.51	0.5	14.2
03OCT83	0.32	7.38	1.0	27.9
04OCT83	0.33	7.51	1.0	28.4
05OCT83	1.25	28.52	2.0	215.9
06OCT83	0.37	8.48	2.0	64.2
07OCT83	0.35	7.92	1.0	30.0
10OCT83	0.34	7.78	1.0	29.5
11OCT83	0.35	7.92	1.0	30.0
12OCT83	0.42	9.49	1.0	35.9
13OCT83	1.23	28.09	4.0	425.4
14OCT83	0.38	8.62	3.0	97.9
17OCT83	.	.	2.0	.
18OCT83	0.34	7.78	3.0	88.4
19OCT83	.	.	2.0	.
20OCT83	0.34	7.78	3.0	88.4

Table 3.1.1 (Continued)

Date	Discharge (m^3/s)	Discharge (mgd)	Hg (µg/L)	Hg Loading (g/d)
21OCT83	0.34	7.65	1.0	28.9
24OCT83	0.40	9.20	2.0	69.6
25OCT83	0.37	8.48	4.0	128.4
26OCT83	0.35	8.06	3.0	91.5
27OCT83	0.35	7.92	4.0	120.0
28OCT83	0.35	7.92	2.0	60.0
31OCT83	0.34	7.78	2.0	58.9
01NOV83	0.35	7.92	3.0	90.0
02NOV83	0.37	8.48	1.0	32.1
03NOV83	0.35	8.06	3.0	91.5
04NOV83	0.65	14.72	3.0	167.2
07NOV83	0.34	7.78	3.0	88.4
08NOV83	0.35	8.06	3.0	91.5
08NOV83	0.35	8.06	3.0	91.5
08NOV83	.	.	3.0	.
09NOV83	0.35	7.92	0.5	15.0
09NOV83	0.38	8.76	4.0	132.7
10NOV83	0.35	8.06	2.0	61.0
10NOV83	0.54	12.25	2.0	92.7
11NOV83	0.35	8.06	1.0	30.5
11NOV83	0.35	7.92	2.0	60.0
14NOV83	0.34	7.65	2.0	57.9
15NOV83	0.62	14.22	2.0	107.6
16NOV83	0.37	8.48	1.0	32.1
17NOV83	0.37	8.34	2.0	63.1
18NOV83	0.34	7.78	2.0	58.9
21NOV83	0.37	8.48	3.0	96.3
22NOV83	0.81	18.43	2.0	139.5
28NOV83	.	.	3.0	.
29NOV83	0.39	8.91	2.0	67.5
30NOV83	0.35	7.92	3.0	90.0
01DEC83	0.34	7.78	2.0	58.9
02DEC83	0.34	7.78	3.0	88.4
05DEC83	0.45	10.38	2.0	78.6
06DEC83	0.68	15.58	1.0	59.0
07DEC83	0.40	9.20	2.0	69.6
08DEC83	0.38	8.62	2.1	68.6
09DEC83	0.38	8.62	2.6	84.9
12DEC83	0.50	11.46	2.2	95.4
13DEC83	0.40	9.20	1.5	52.2
14DEC83	0.47	10.69	1.6	64.7
15DEC83	0.37	8.48	1.5	48.2
19DEC83	0.34	7.78	3.6	106.1
20DEC83	0.34	7.78	2.4	70.7
21DEC83	0.34	7.78	1.6	47.1

Table 3.1.1 (Continued)

Date	Discharge (m^3/s)	Discharge (mgd)	Hg (µg/L)	Hg Loading (g/d)
22DEC83	1.04	23.79	0.8	72.0
27DEC83	0.35	7.92	2.6	78.0
28DEC83	1.23	28.09	2.4	255.3
29DEC83	0.42	9.64	3.6	131.3
30DEC83	0.37	8.48	2.5	80.3
03JAN84	0.39	8.96	3.1	105.2
04JAN84	0.40	9.04	1.9	65.0
05JAN84	0.40	9.06	1.3	44.6
06JAN84	0.40	9.14	1.7	58.8
09JAN84	0.38	8.70	3.6	118.6
10JAN84	0.55	12.48	2.8	132.3
11JAN84	0.46	10.57	2.6	104.0
12JAN84	0.43	9.90	2.8	104.9
13JAN84	0.44	9.98	5.1	192.7
14JAN84	0.41	9.43	3.2	114.2
15JAN84	0.40	9.21	3.4	118.6
16JAN84	0.43	9.91	4.0	150.1
17JAN84	0.42	9.65	3.3	120.6
18JAN84	0.69	15.83	6.0	359.6
19JAN84	0.49	11.07	2.4	100.6
20JAN84	0.40	9.24	2.6	91.0
23JAN84	0.40	9.19	3.0	104.4
24JAN84	0.67	15.30	2.3	133.2
26JAN84	0.57	13.04	2.4	118.5
27JAN84	0.73	16.76	1.9	120.6
30JAN84	0.39	8.94	2.3	77.8
31JAN84	0.40	9.17	3.7	128.5
01FEB84	0.39	8.93	2.0	67.6
02FEB84	0.39	8.87	2.1	70.5
03FEB84	0.41	9.39	2.2	78.2
06FEB84	0.41	9.29	2.6	91.4
07FEB84	0.41	9.34	2.6	91.9
08FEB84	0.41	9.34	1.6	56.6
09FEB84	0.41	9.34	2.5	88.4
10FEB84	0.46	10.43	2.0	79.0
13FEB84	0.72	16.35	2.0	123.8
14FEB84	0.61	13.94	2.0	105.6
15FEB84	0.49	11.16	2.4	101.4
16FEB84	0.47	10.79	1.5	61.3
17FEB84	0.45	10.18	2.1	80.9
21FEB84	0.39	8.88	2.9	97.5
22FEB84	0.41	9.34	2.7	95.5
23FEB84	0.54	12.33	1.8	84.0

Table 3.1.1 (Continued)

Date	Discharge (m^3/s)	Discharge (mgd)	Hg (µg/L)	Hg Loading (g/d)
24FEB84	0.42	9.56	1.7	61.5
27FEB84	0.78	17.82	3.9	263.1
28FEB84	0.60	13.58	1.1	56.6
29FEB84	0.46	10.59	2.3	92.2
01MAR84	0.40	9.05	1.7	58.2
02MAR84	0.39	8.81	1.4	46.7
05MAR84	0.39	8.89	2.4	80.8
06MAR84	0.40	9.05	2.0	68.5
07MAR84	0.37	8.47	1.9	60.9
08MAR84	0.35	7.98	2.0	60.4
09MAR84	0.34	7.78	2.0	58.9
12MAR84	0.34	7.65	3.2	92.7
13MAR84	0.38	8.66	2.2	72.1
14MAR84	0.36	8.25	1.7	53.1
15MAR84	0.35	8.06	3.0	91.5
16MAR84	0.42	9.61	1.1	40.0
19MAR84	0.36	8.27	2.1	65.8
20MAR84	0.58	13.25	1.6	80.3
21MAR84	0.57	12.95	1.5	73.5
22MAR84	0.45	10.38	1.2	47.2
23MAR84	0.41	9.31	1.7	59.9
17APR84	.	.	1.8	.
18APR84	.	.	2.5	.
19APR84	0.36	8.14	1.7	52.4
23APR84	0.42	9.52	1.8	64.9
24APR84	0.39	8.82	1.6	53.4
25APR84	0.39	8.82	1.8	60.1
26APR84	0.37	8.43	1.5	47.9
27APR84	0.41	9.34	1.4	49.5
30APR84	0.43	9.87	1.3	48.6
01MAY84	0.40	9.17	1.2	41.7
02MAY84	0.67	15.27	1.8	104.1
03MAY84	0.78	17.81	6.5	438.3
04MAY84	0.57	13.06	1.6	79.1
07MAY84	1.30	29.71	6.6	742.4
08MAY84	1.11	25.44	2.8	269.7
09MAY84	0.64	14.65	1.9	105.4
10MAY84	0.52	11.90	1.8	81.1
11MAY84	0.46	10.41	2.0	78.8
14MAY84	0.46	10.41	2.3	90.6
15MAY84	0.42	9.69	2.3	84.4
16MAY84	0.42	9.52	2.3	82.9
17MAY84	0.41	9.34	2.0	70.7
18MAY84	0.40	9.17	2.2	76.4

Table 3.1.1 (Continued)

Date	Discharge (m^3/s)	Discharge (mgd)	Hg (µg/L)	Hg Loading (g/d)
21MAY84	0.38	8.65	2.1	68.8
22MAY84	0.39	8.82	1.9	63.4
23MAY84	0.42	9.69	2.2	80.7
24MAY84	0.35	7.98	1.6	48.3
25MAY84	0.34	7.81	2.3	68.0
29MAY84	0.42	9.52	1.7	61.3
30MAY84	0.38	8.65	2.2	72.0
31MAY84	0.38	8.65	1.7	55.7
01JUN84	0.36	8.31	2.6	81.8
04JUN84	0.34	7.81	2.3	68.0
05JUN84	0.34	7.81	2.2	65.0
06JUN84	0.35	7.98	2.6	78.6
07JUN84	0.34	7.81	2.6	76.9
08JUN84	0.31	7.00	2.0	53.0
11JUN84	0.31	7.16	2.2	59.6
12JUN84	0.33	7.48	1.9	53.8
13JUN84	0.33	7.48	1.8	51.0
14JUN84	0.57	13.06	2.0	98.9
15JUN84	0.38	8.65	2.6	85.1
18JUN84	0.35	7.97	2.1	63.4
19JUN84	0.40	9.17	1.9	66.0
20JUN84	0.45	10.23	1.4	54.2
21JUN84	0.44	10.05	1.3	49.5
22JUN84	0.39	8.99	1.5	51.1
25JUN84	0.33	7.48	1.2	34.0
26JUN84	0.32	7.32	1.5	41.6
27JUN84	0.32	7.32	1.2	33.3
28JUN84	0.33	7.48	1.5	42.5
29JUN84	0.62	14.25	1.1	59.3
02JUL84	0.36	8.31	1.6	50.3
03JUL84	0.36	8.14	1.3	40.1
05JUL84	.	.	2.6	.
06JUL84	.	.	4.8	.
09JUL84	.	.	2.1	.
10JUL84	.	.	5.6	.
11JUL84	.	.	2.5	.

Table 3.1.2. Monthly composite sample data for mercury in
New Hope Pond effluent for December 1977–July 1984

Month	Year	Total Monthly Discharge (10^6 gal)	Total Monthly Discharge (M^3)	Hg (μg/L)	Hg Loading (kg)
12	1977	210	794850	0.5	0.40
1	1978	315	1192275	2.5	2.98
2	1978	285	1078725	1.5	1.62
3	1978	280	1059800	1.0	1.06
4	1978	185	700225	0.5	0.35
5	1978	280	1059800	0.5	0.53
6	1978	220	832700	0.5	0.42
7	1978	210	794850	0.5	0.40
8	1978	245	927325	0.5	0.46
9	1978	185	700225	0.5	0.35
10	1978	160	605600	0.5	0.30
11	1978	210	794850	1.0	0.79
12	1978	240	908400	1.0	0.91
1	1979	285	1078725	0.5	0.54
2	1979	220	832700	0.5	0.42
3	1979	245	927325	0.5	0.46
4	1979	230	870550	0.5	0.44
5	1979	230	870550	0.5	0.44
6	1979	220	832700	0.5	0.42
7	1979	280	1059800	4.0	4.24
8	1979	240	908400	3.0	2.73
9	1979	210	794850	0.5	0.40
10	1979	210	794850	1.0	0.79
11	1979	235	889475	3.0	2.67
12	1979	210	794850	1.0	0.79
1	1980	285	1078725	2.0	2.16
2	1980	205	775925	1.0	0.78
3	1980	370	1400450	0.5	0.70
4	1980	250	946250	0.5	0.47
5	1980	255	965175	0.5	0.48
6	1980	265	1003025	0.5	0.50
7	1980	225	851625	0.5	0.43
8	1980	230	870550	1.0	0.87
9	1980	235	889475	3.0	2.67
10	1980	285	1078725	0.5	0.54
11	1980	265	1003025	1.0	1.00
12	1980	230	870550	0.5	0.44
1	1981	212	802420	2.0	1.60
2	1981	237	897045	2.0	1.79
3	1981	230	870550	1.0	0.87
4	1981	210	794850	1.0	0.79
5	1981	210	794850	1.0	0.79
6	1981	240	908400	1.0	0.91

Table 3.1.2 (Continued)

Month	Year	Total Monthly Discharge (10^6 gal)	Total Monthly Discharge (M^3)	Hg ($\mu g/L$)	Hg Loading (kg)
7	1981	230	870550	1.0	0.87
8	1981	195	738075	0.5	0.37
9	1981	205	775925	0.5	0.39
10	1981	200	757000	2.0	1.51
11	1981	190	719150	1.0	0.72
12	1981	200	757000	0.5	0.38
1	1982	280	1059800	1.0	1.06
2	1982	350	1324750	1.0	1.32
3	1982	305	1154425	1.0	1.15
4	1982	240	908400	1.0	0.91
5	1982	235	889475	0.5	0.44
6	1982	245	927325	0.5	0.46
7	1982	280	1059800	1.0	1.06
8	1982	287	1086295	1.0	1.09
9	1982	275	1040875	7.0	7.29
10	1982	260	984100	0.5	0.49
11	1982	310	1173350	0.5	0.59
12	1982	330	1249050	1.0	1.25
1	1983	255	965175	1.0	0.97
2	1983	285	1078725	0.5	0.54
3	1983	275	1040875	0.5	0.52
4	1983	300	1135500	1.0	1.14
5	1983	300	1135500	0.5	0.57
6	1983	244	923540	0.5	0.46
7	1983	268	1014380	0.5	0.51
8	1983	251	950035	0.5	0.48
9	1983	236	893260	0.5	0.45
10	1983	268	1014380	0.5	0.51
11	1983	282	1067370	.	.
12	1983	310	1173350	2.4	2.82
1	1984	318	1203630	1.2	1.44
2	1984	300	1135500	1.5	1.70
3	1984	285	1078725	0.8	0.86
4	1984	271	1025735	0.3	0.26
5	1984	362	1370170	1.7	2.33
6	1984	257	972745	.	.

concentration, and n = number of values. Flow-weighted averages are more appropriate than arithmetic means for comparison with the monthly composite values. The flow-weighted average concentration of a constituent should be equivalent to the concentration of that constituent in a fully mixed composite of all water discharged during the period of interest.

Table 3.1.3 and Fig. 3.1.1 compare the monthly flow-weighted average mercury concentration with the monthly composite concentrations. The two data sets are not very comparable. In most cases the flow-weighted average values are higher than the composite values. These discrepancies suggest that one of the data sets may be in error due to analytical or sampling reasons. Because mercury is known to be lost by sorption to container walls and by volatilization from unpreserved water samples (Jenne and Avotins 1975), the composite values (based on samples which were unpreserved for up to 30 days) might be expected to be lower than the grab sample values. Grab samples were preserved within a few hours of collection, or collected in bottles containing preservative. The grab sample data could also be non-representative because, prior to July 1983, as few as four samples per month were used to calculate a monthly average value. Between July 1983 and June 1984, grab samples were collected on nearly every weekday but the monthly flow-weighted average values are still higher (one exception) than the monthly composite values (Table 3.1.3).

The use of flow-weighted average translates into higher monthly and cumulative mercury loading of EFPC than the use of monthly composite values. Figure 3.1.2 displays the cumulative mercury loading

Table 3.1.3. Comparison of monthly flow-weighted mean(grab) and
monthly composite Hg concentrations

Month	Year	Grab Hg (µg/L)	Composite Hg (µg/L)
12	1977	3.2	0.5
1	1978	3.2	2.5
2	1978	3.1	1.5
3	1978	1.3	1.0
4	1978	2.2	0.5
5	1978	1.2	0.5
6	1978	1.0	0.5
7	1978	0.7	0.5
8	1978	1.3	0.5
9	1978	0.5	0.5
10	1978	0.5	0.5
11	1978	1.2	1.0
12	1978	1.2	1.0
1	1979	2.1	0.5
2	1979	1.6	0.5
3	1979	2.2	0.5
4	1979	1.8	0.5
5	1979	1.1	0.5
6	1979	1.2	0.5
7	1979	1.6	4.0
8	1979	1.6	3.0
9	1979	1.1	0.5
10	1979	2.0	1.0
11	1979	1.1	3.0
12	1979	1.8	1.0
1	1980	1.6	2.0
2	1980	3.2	1.0
3	1980	2.3	0.5
4	1980	1.9	0.5
5	1980	2.0	0.5
6	1980	2.2	0.5
7	1980	1.3	0.5
8	1980	1.0	1.0
9	1980	1.1	3.0
10	1980	1.6	0.5
11	1980	2.0	1.0
12	1980	1.6	0.5
1	1981	2.6	2.0
2	1981	2.6	2.0
3	1981	1.5	1.0
4	1981	1.6	1.0
5	1981	1.5	1.0
6	1981	0.6	1.0

Table 3.1.3 (Continued)

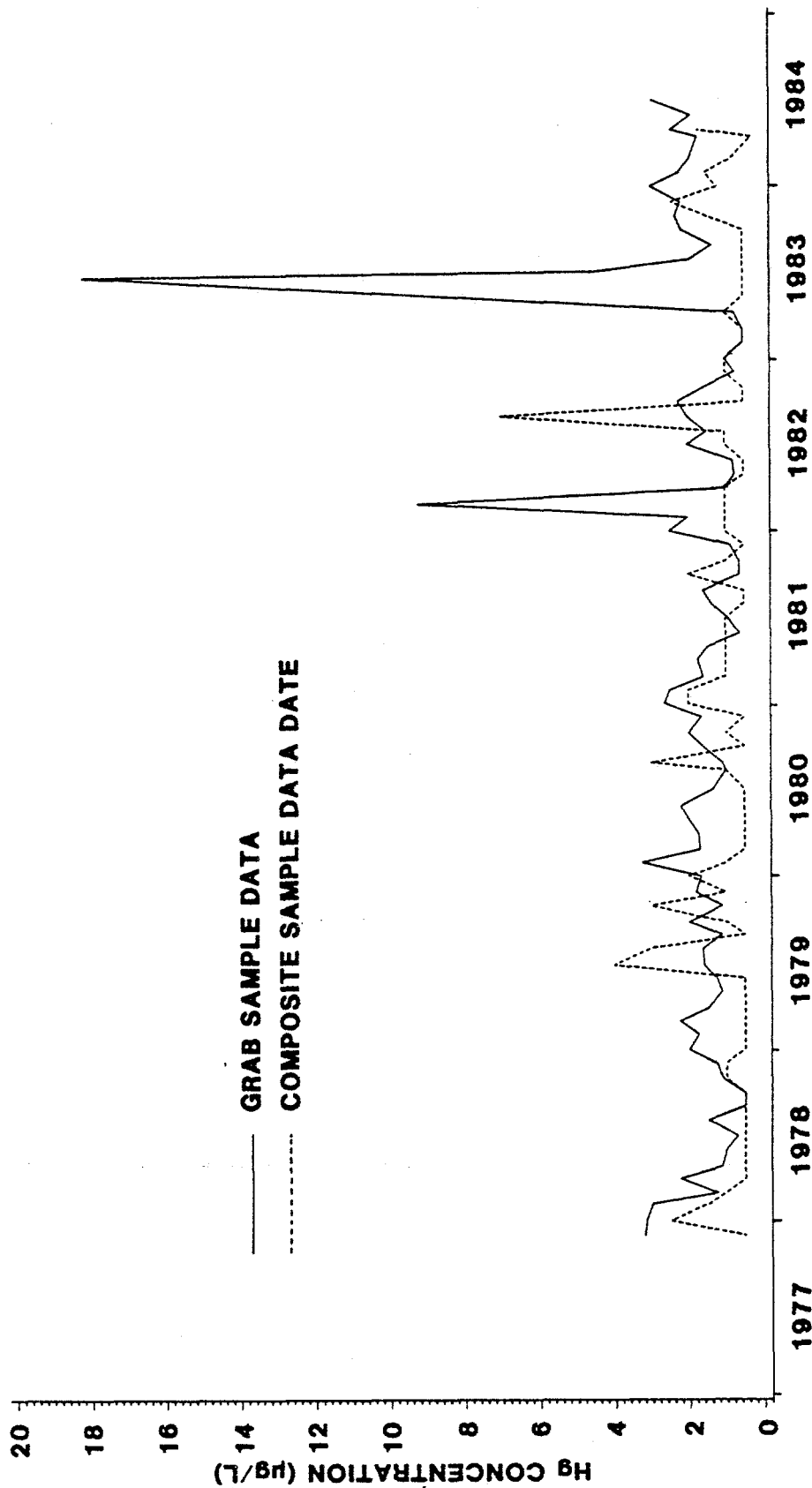| Month	Year	Grab Hg (μg/L)	Composite Hg (μg/L)
7	1981	0.9	1.0
8	1981	1.4	0.5
9	1981	1.6	0.5
10	1981	0.6	2.0
11	1981	0.6	1.0
12	1981	0.9	0.5
1	1982	2.4	1.0
2	1982	2.0	1.0
3	1982	18.3	1.0
4	1982	1.0	1.0
5	1982	0.8	0.5
6	1982	0.8	0.5
7	1982	2.0	1.0
8	1982	1.8	1.0
9	1982	2.3	7.0
10	1982	2.2	0.5
11	1982	1.6	0.5
12	1982	0.8	1.0
1	1983	1.0	1.0
2	1983	0.5	0.5
3	1983	0.5	0.5
4	1983	0.7	1.0
5	1983	.	0.5
6	1983	21.3	0.5
7	1983	4.6	0.5
8	1983	1.9	0.5
9	1983	1.3	0.5
10	1983	2.3	0.5
11	1983	2.3	.
12	1983	2.0	2.4
1	1984	3.0	1.2
2	1984	2.2	1.5
3	1984	1.9	0.8
4	1984	1.6	0.3
5	1984	2.9	1.7
6	1984	1.9	.
7	1984	1.5	.

Fig. 3.1.1. Comparison of monthly composite sample data (dashed line) for mercury concentration in NHP effluent with monthly flow-weighted averages based on grab sample data (solid line).
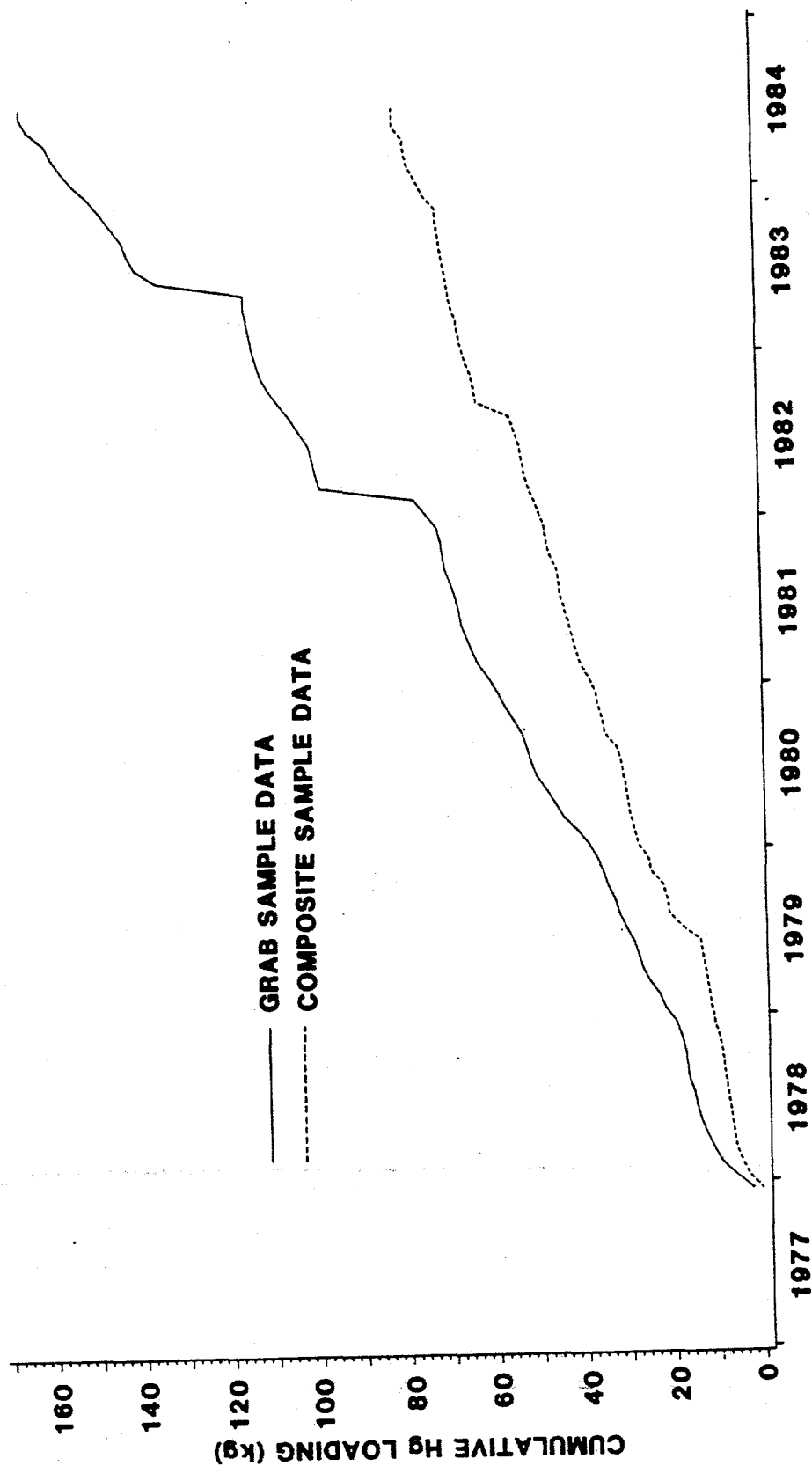
Fig. 3.1.2. Comparison of cumulative mercury loading of EFPC calculated using grab sample data and composite sample data

of EFPC since 1977 as calculated using each data set. The two sharp increases in cumulative loading correspond with periods (March 1982 and June 1983) when higher than normal mercury concentrations occurred in at least one grab sample taken during the month. Stormflow appears to account for the single high value (40 µg/L) in March 1982 (note discharge >27 mgd), while the values for June 1983 relate to a water line break in the basement of Building 9201-4 which washed considerable mercury into the industrial ditch. Neither of these 'events' are detectable in the cumulative loading plot (Fig. 3.1.2) for the composite data. It is very reasonable to expect the March 1982 'event' (i.e., a single grab sample) not to be detectable in the composite sample for that month. On the other hand, the June 1983 water line break elevated mercury concentrations in NHP effluent for several days and should have been detected as a higher concentration in the monthly composite.

Overall the comparison of grab and composite sample data suggests that the grab sample data should be used to establish the average and range of Hg concentrations and loadings and to evaluate short- and long-term trends in the monitoring data. Whether the composite samples should continue to be analyzed for mercury is an issue involving the NPDES permit and beyond the scope of this study.

Short- and long-term trends in the NHP monitoring data (grab samples) were sought in two ways. First, mercury concentrations and loadings were averaged for the entire period and for each year since 1977.(Table 3.1.4). The overall, long-term (post 1977), average mercury concentration and loading values for NHP effluent are 2.9 µg/L and

Table 3.1.4. Summary (mean $\pm$ SD) of weekly grab sample data by year for mercury in New Hope Pond effluent (NPDES station)

Year	Mercury concentration (µg/L)	No. of observations	Mercury loading (g/day)	No. of observations
1977	3.2 $\pm$ 0.4	5	45 $\pm$ 20	5
1978	1.6 $\pm$ 1.1	55	31 $\pm$ 21	52
1979	1.6 $\pm$ 0.9	53	45 $\pm$ 33	53
1980	1.8 $\pm$ 1.0	44	53 $\pm$ 27	41
1981	1.4 $\pm$ 0.9	51	40 $\pm$ 30	51
1982[a]	2.8 $\pm$ 5.4	52	210 $\pm$ 1080	49
1983	5.0 $\pm$ 11	185	174 $\pm$ 430	171
1984[b]	2.3 $\pm$ 1.0	118	92 $\pm$ 84	111
$\overline{X}$ =	2.9 $\pm$ 6.8	563	104 $\pm$ 310	533

[a]One outlier value (40 µg/L concentration, >27 Mgd flow) included. Excluding outlier yields 1.5 $\pm$ 0.8 µg/L and 23 $\pm$ 18 g/day.

[b]Data through June 1984 only.

100 g/d, respectively. Note, however, that the standard deviations on both these values are large, attesting to high variability. Mercury concentrations have varied from 0.5 to 99 µg/l whereas loading has varied from 10 to >4000 g/d. For the years 1978 through 1982, the number of observations, average mercury concentration, and loading values are reasonably similar (especially if the one high outlier value is excluded). For this five year period, typical effluent concentrations were ~ 2 µg/L, whereas typical loading values were ~ 50 g/d. Beginning in 1983, average mercury concentration and loading values show a significant increase over earlier values. The high 1983 average values reflect the influence of the waterline break in Building 9201-4 and the higher frequency of sampling during 1983 than earlier. As sampling frequency increases, the probability of sampling stormflow events and plant upsets (eg. the waterline break) also increases. Stormflow and some plant upsets are expected to result in higher values for both mercury concentration and loading. Flows in excess of 10 mgd (0.44 m³/s) at NHP are typically indicative of stormflow conditions. Between December 1977 and May 1983 (period of weekly sampling) flows at NHP in excess of 10 mgd were sampled 26 times (~10% of all sampled flows). In contrast, between June 1983 and June 1984, 48 flows (~20% of all sampled flows) in excess of 10 mgd were sampled. Thus the 1983 and 1984 averages include a higher percentage of stormflow data and are accordingly higher than the earlier averages. The 1983 averages also include observations from the June 1983 waterline break and are thus higher than the 1984 averages. The long-term (1977-1984) trends in total monthly discharge, monthly flow-weighted average mercury concentration, and average

ORNL-DWG 85-1729
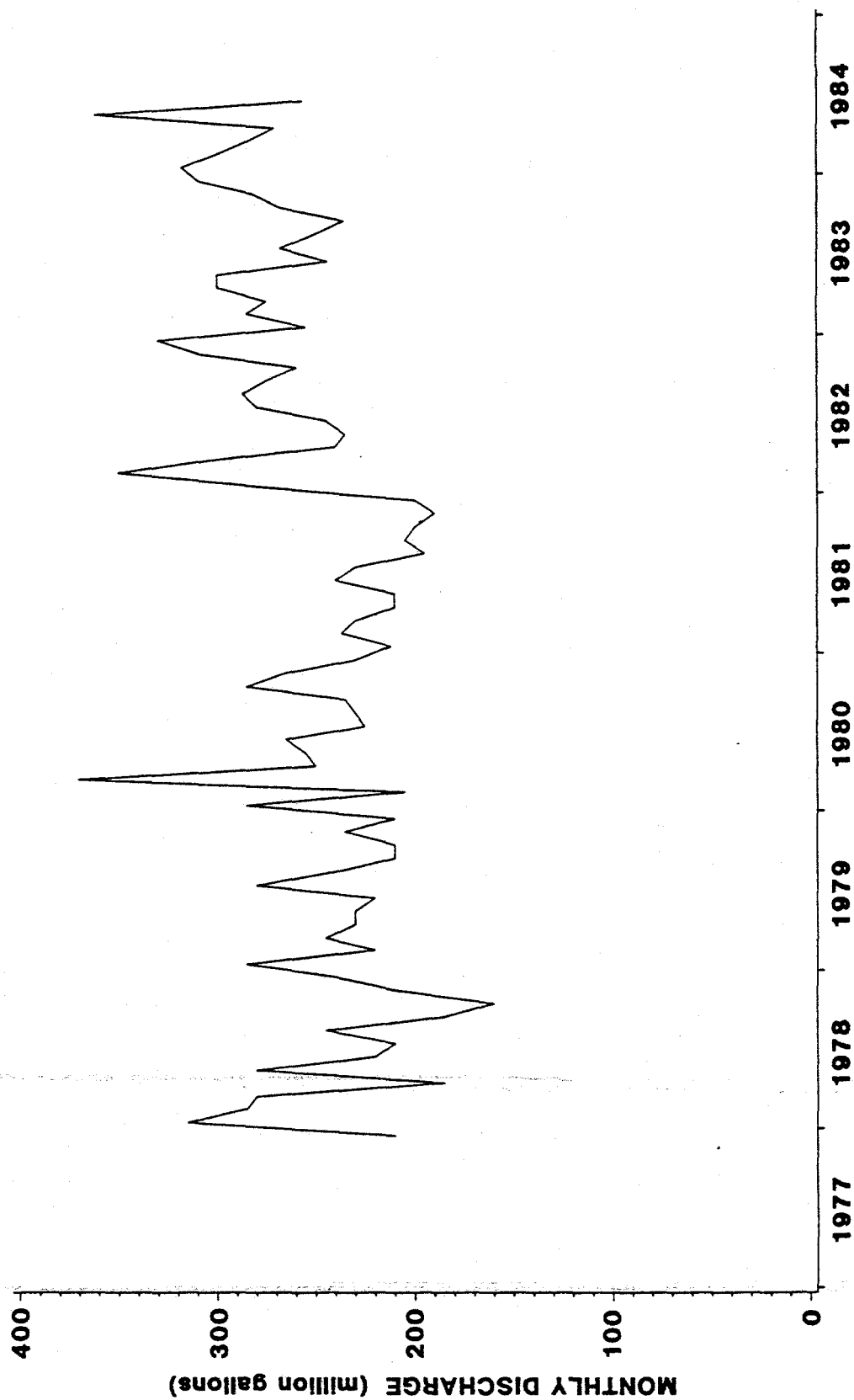
Fig. 3.1.3. Total monthly water discharge from NHP for the period
December 1977 through May 1984
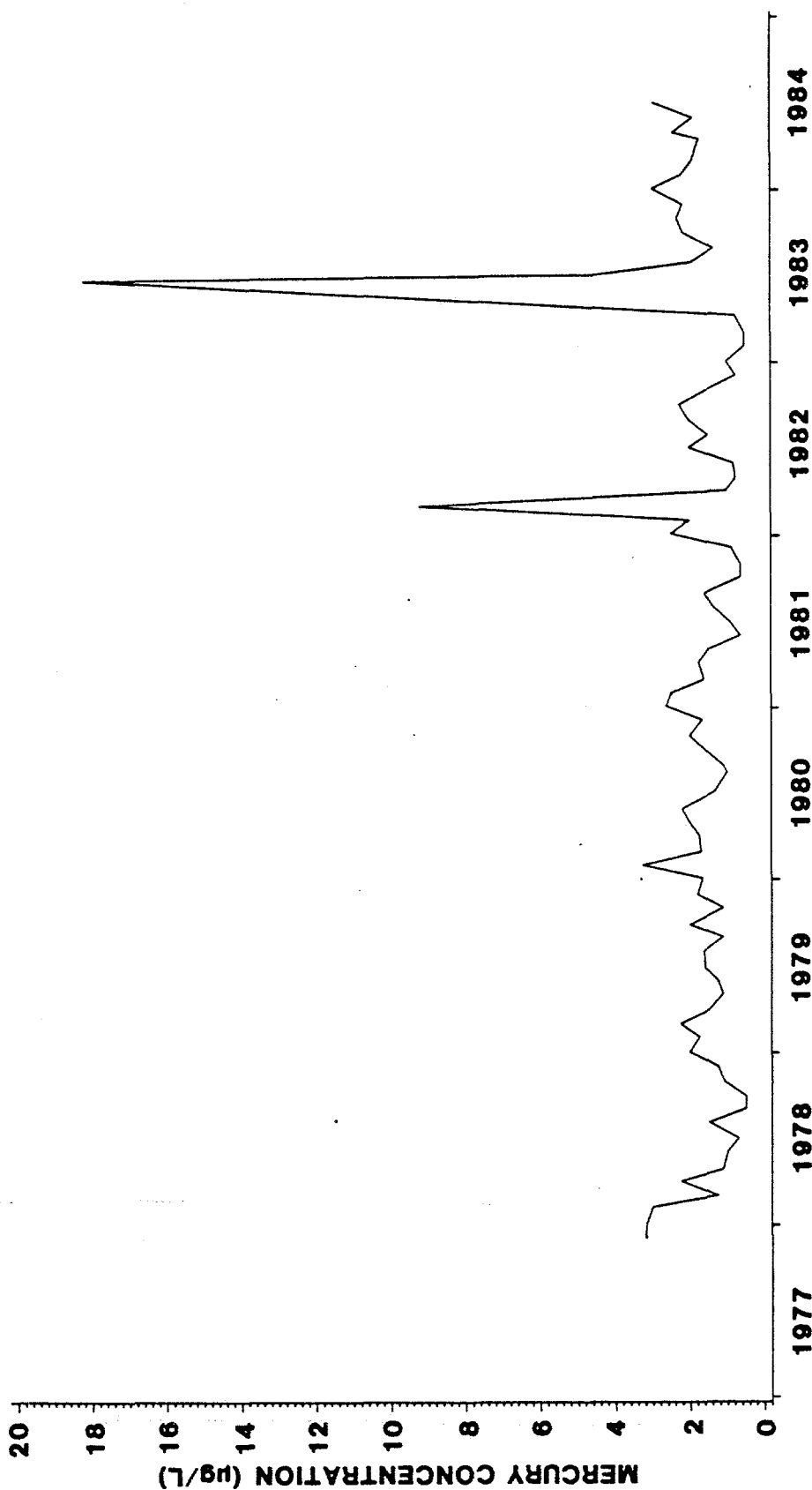
ORNL-DWG 85-1726

Fig. 3.1.4. Monthly flow-weighted average mercury concentrations for
NHP effluent for the period December 1977 through May
1984.

ORNL-DWG 85-1730
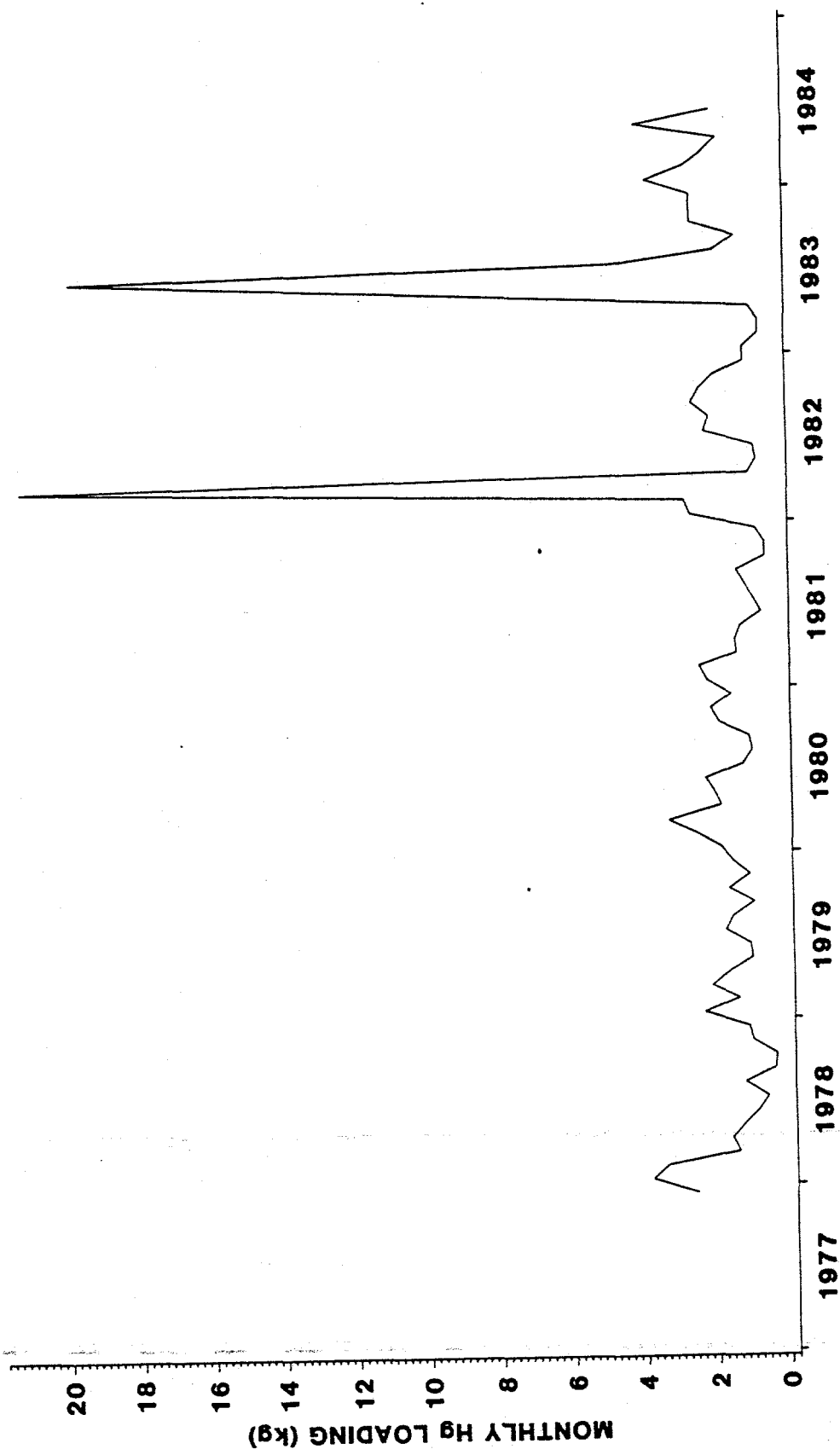
Fig. 3.1.5. Monthly mercury loading for NHP effluent for the period
December 1977 through May 1984.

monthly mercury loading are also displayed graphically in Figures 3.1.3, 3.1.4 and 3.1.5.

NHP effluent data for the period July 1983-June 1984 were examined for evidence of short-term trends. The data for this period represent daily (except weekends) grab sample results, including 48 observations when discharge exceeded 10 mgd (i.e., stormflow). Daily rainfall and discharge (at time of sampling only) for this period are displayed in Figure 3.1.6. Nearly every peak in discharge corresponds with a rainfall event but the discharge peaks are not proportional to rainfall amounts. This lack of proportionality was expected because the discharge data are for the time of water sampling only and thus do not represent complete hydrographs for each storm. Peaks in effluent mercury concentration (Figure 3.1.7) do not, in general, correspond with peaks in discharge. Some peaks in concentration, such as those in early May 1984, do correspond with discharge peaks, but in general the correlation between mercury concentration and discharge is poor. For example, the high concentration peaks (10 and 12 mg/L) in early July 1983 do not correspond with peaks in discharge. The early July 1983, concentration peaks appear to be related to the June 23 waterline break in Building 9201-4, the effects of which persisted well into July. Although mercury concentrations are not well correlated with discharge, mercury loading (g/d) is reasonably well correlated with discharge (r=0.62 p<0.01). In part, this correlation derives from the fact that loading is the product of discharge and concentration.

ORNL-DWG 85-1733
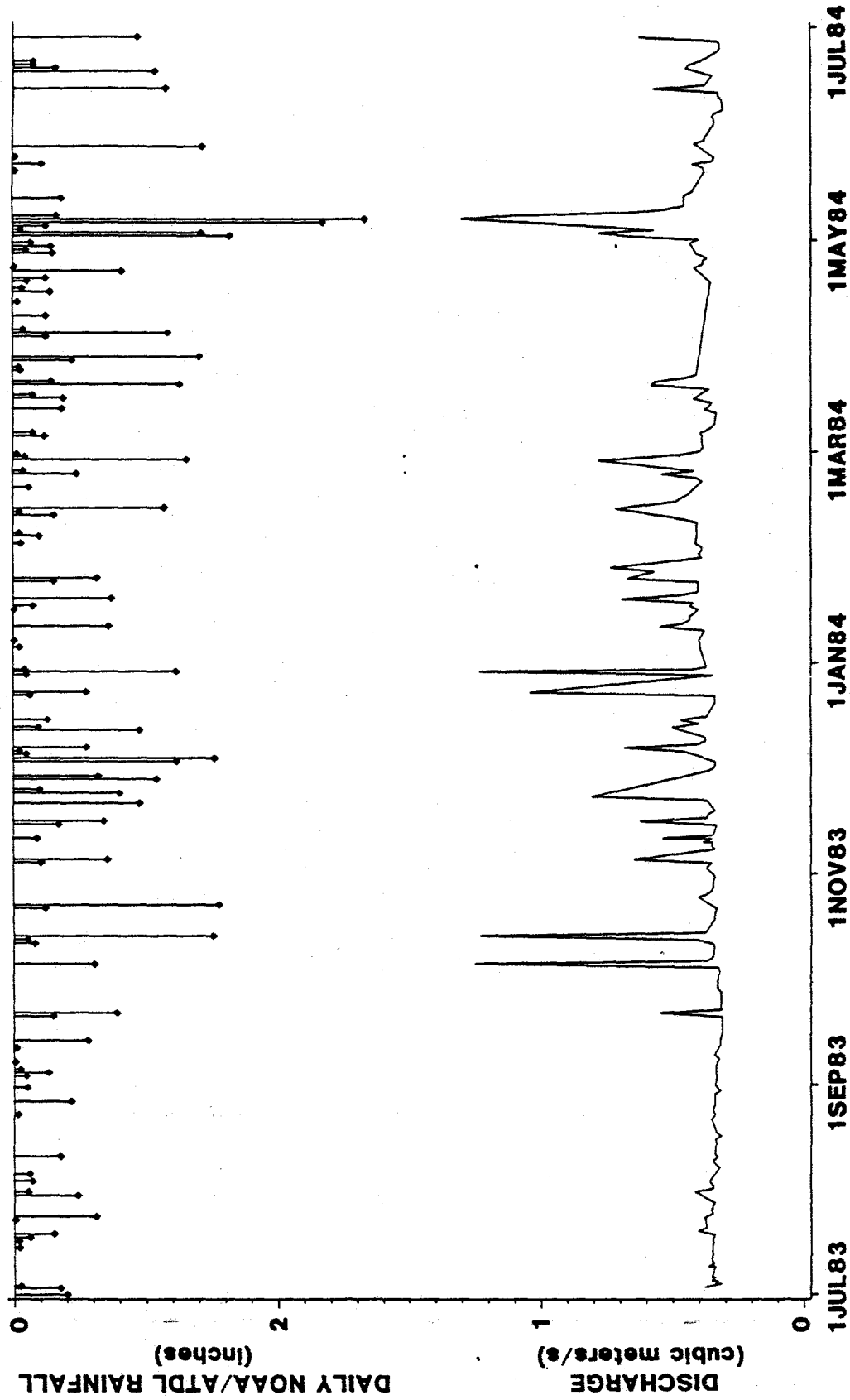
Fig. 3.1.6. Daily rainfall and NHP discharge (at time of water sampling) for the period July 1983 through June 1984.

ORNL-DWG 85-1732
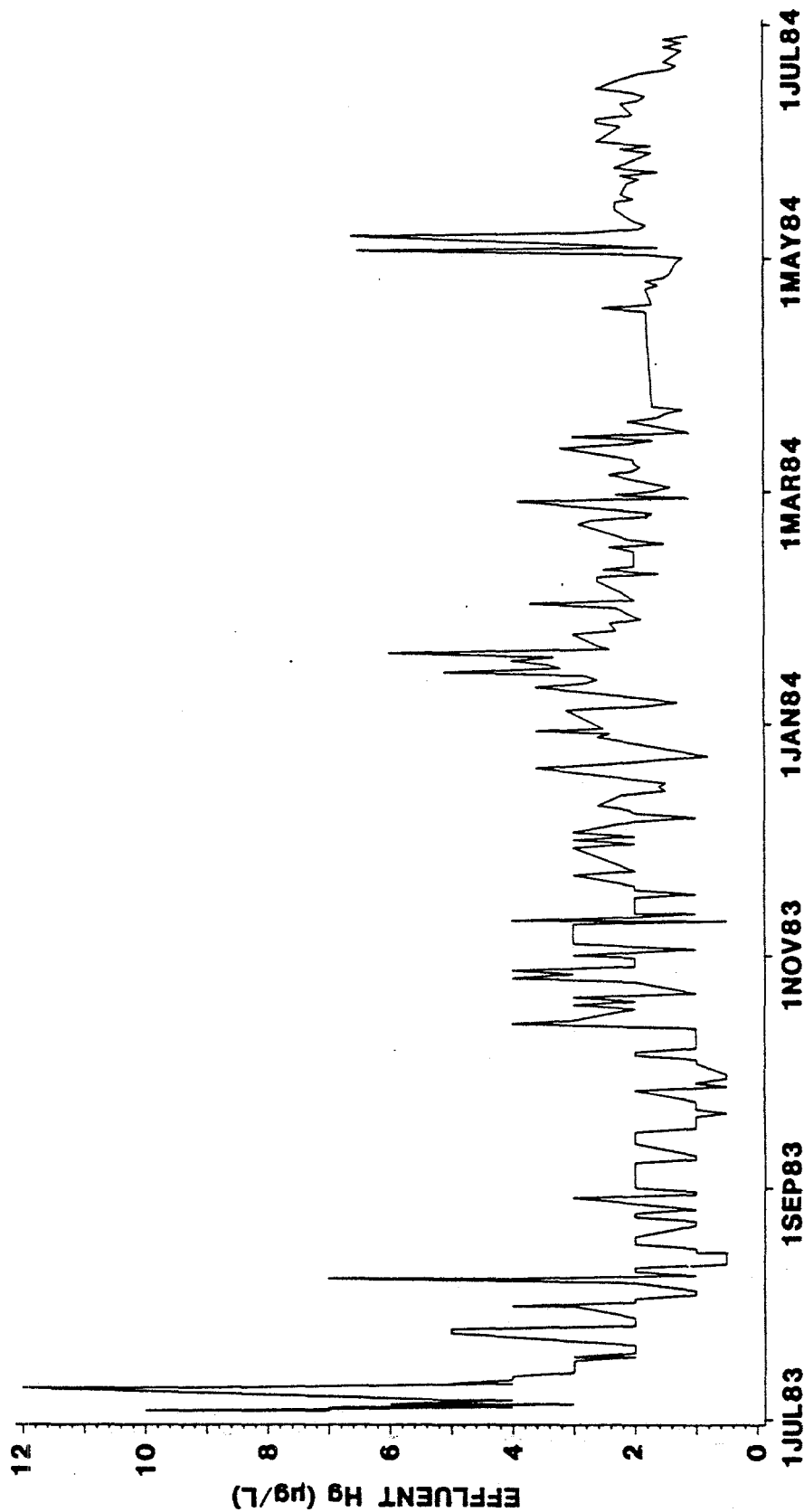
Fig. 3.1.7. Temporal variations mercury concentration in NHP effluent
for the period July 1983 through June 1984.

In summary, the daily grab sample data for 1983-84 show short-term
trends in mercury concentration and loading which appear to be related to
both rainfall and to Y-12 Plant operations (or upsets). Additional recent
data and evaluation of short-term trends are given in Section 3.5 "On-line
Monitoring."

3.2 Mass Balance of Mercury for New Hope Pond

The bottom deposits in New Hope Pond contain mercury at concentrations
up to 300 µg/g (Van Winkle et al., 1982). Most of these deposits have been
accumulating since 1973 when the pond was partially dredged. Thus the pond
is acting as a settling basin for mercury-contaminated solids transported
into it from the plant. The effectiveness, or trap efficiency, of NHP as a
settling basis for mercury-contaminated solids has not previously been
evaluated but is important in the overall assessment of mercury losses from
the plant.   Trap efficiency of NHP has been estimated using the
available monitoring data plus additional data generated as a part of this
study. Trap efficiency, expressed as a percent, is calculated as

$$\frac{\text{Hg Influx} - \text{Hg Efflux}}{\text{Hg Influx}} \times 100$$

where influx and efflux are in loading units, g/day, and can be
instantaneous values or averages. Instantaneous values of trap efficiency
can be misleading because of short-term changes in pond storage, such as
may occur during pulse loading (i.e., stormflow, spills). Values of trap
efficiency calcuated for periods of steady-state influxes and effluxes are
more representative.
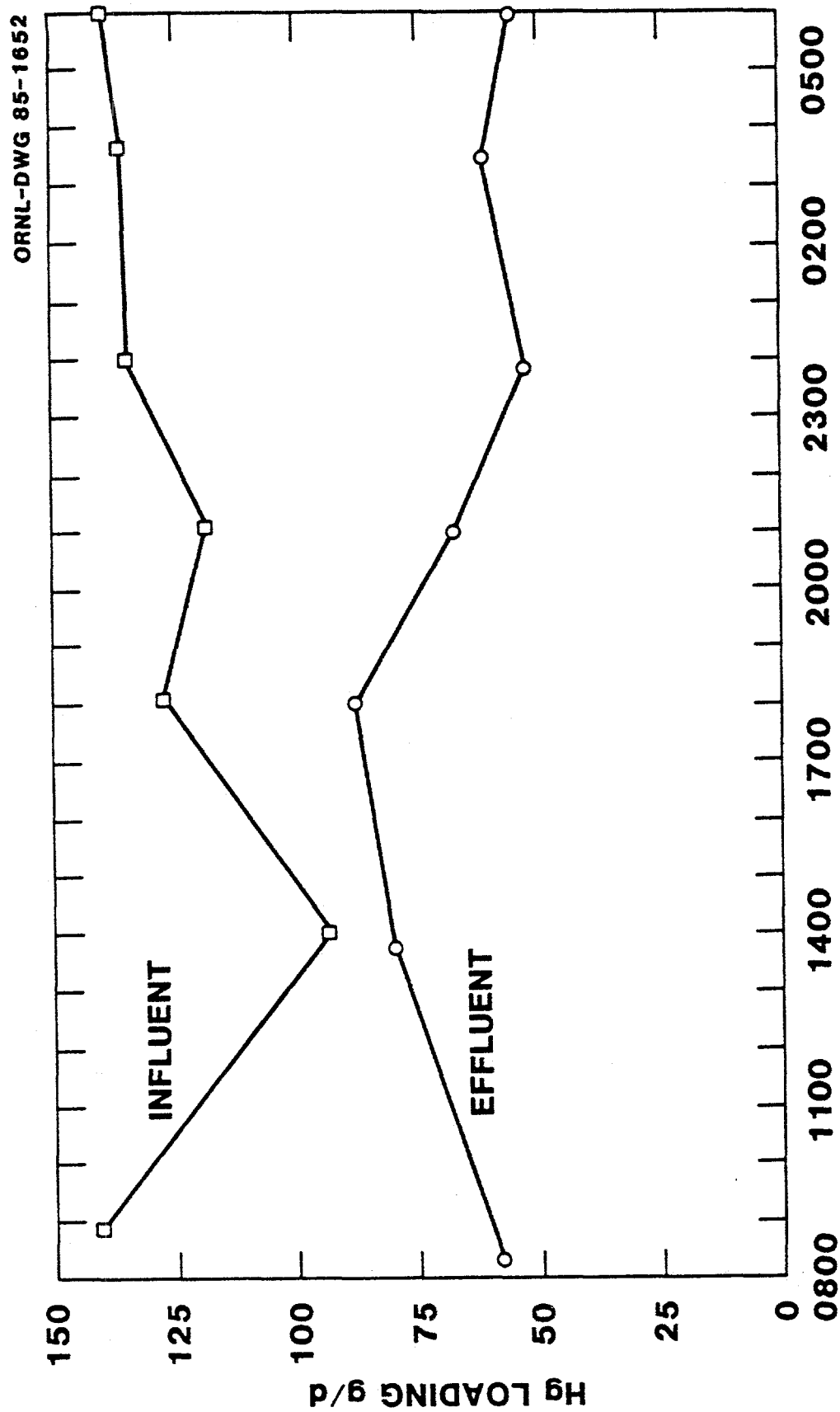
Fig. 3.2.1. Mercury loading for the inflow and outflow of NHP for the period October 28-29, 1982.

Initially (October 28-29, 1982) the pond influent and effluent were sampled at ~4-hr intervals over a 24-hr weekday period. Figure 3.2.1 displays the mercury loading data for this period. Instantaneous mercury trap efficiency values ranged from 17% for the midafternoon observation to 60% for the midnight observation. Flow of water through the pond was slightly higher during daylight hours and may partially explain the lower mercury trap efficiency during daylight hours. Trap efficiency was expected to vary inversely with water flow (see later discussion).

Mercury trap efficiency of NHP was evaluated on a longer term basis using the data for July 1983 through June 1984. During this period pond influent and effluent samples were collected on a daily basis, except for weekends. Monthly flow-weighted average influent and effluent concentrations were calculated and then multiplied by total monthly flow (inflow to NHP assumed to be equal to measured outflow). The resulting total monthly mercury loadings are shown in Fig. 3.2.2 and tabulated with related data in Table 3.2.1.

The high concentration and loading values shown in Fig. 3.2.2 for July 1983 resulted from a water main break in the basement of Building 9201-4 on June 22, 1983, the effects of which extended well into July 1983. The July 1983 data are thus not representative of steady state conditions. Trap efficiency ranged from 16% in May 1984 to 74% in August 1983. The two lowest values (16% and 25%) for trap efficiency occurred during April and May 1984 when construction of the NHP by-pass channel required the dispersion ditch to be shut off. Inflow to the pond during this period was not afforded the thorough mixing provided by the dispersion system and

Table 3.2.1. Monthly mercury concentrations and loadings
for New Hope Pond, July 1983 – June 1984

	Influent Hg concentration[a] (g/L)	Effluent Hg concentration[a] (g/L)	Total flow (10^6 gal)	Influent Hg loading (kg)	Effluent Hg loading (kg)	Trap efficiency (%)
1983						
July	13	4.6	268	13	4.6	65
August	7.1	1.9	251	6.7	1.8	74
September	3.9	1.3	236	3.5	1.2	67
October	5.6	2.3	268	5.7	2.4	59
November	4.3	2.2	282	4.6	2.4	47
December	5.0	2.0	310	5.8	2.4	59
1984						
January	4.4	3.0	318	5.3	3.6	31
February	3.4	2.2	300	3.9	2.5	35
March	4.0	1.9	285	4.4	2.0	54
April	2.1	1.6	271	2.2	1.6	25
May	3.4	2.8	362	4.6	3.9	16
June	3.6	1.8	257	3.5	1.8	49

[a]Value given is flow-weighted average of daily values.

ORNL-DWG 85-1728

MONTHLY Hg LOADING (kg)

MONTH

EFFLUX
INFLUX

1983   1984
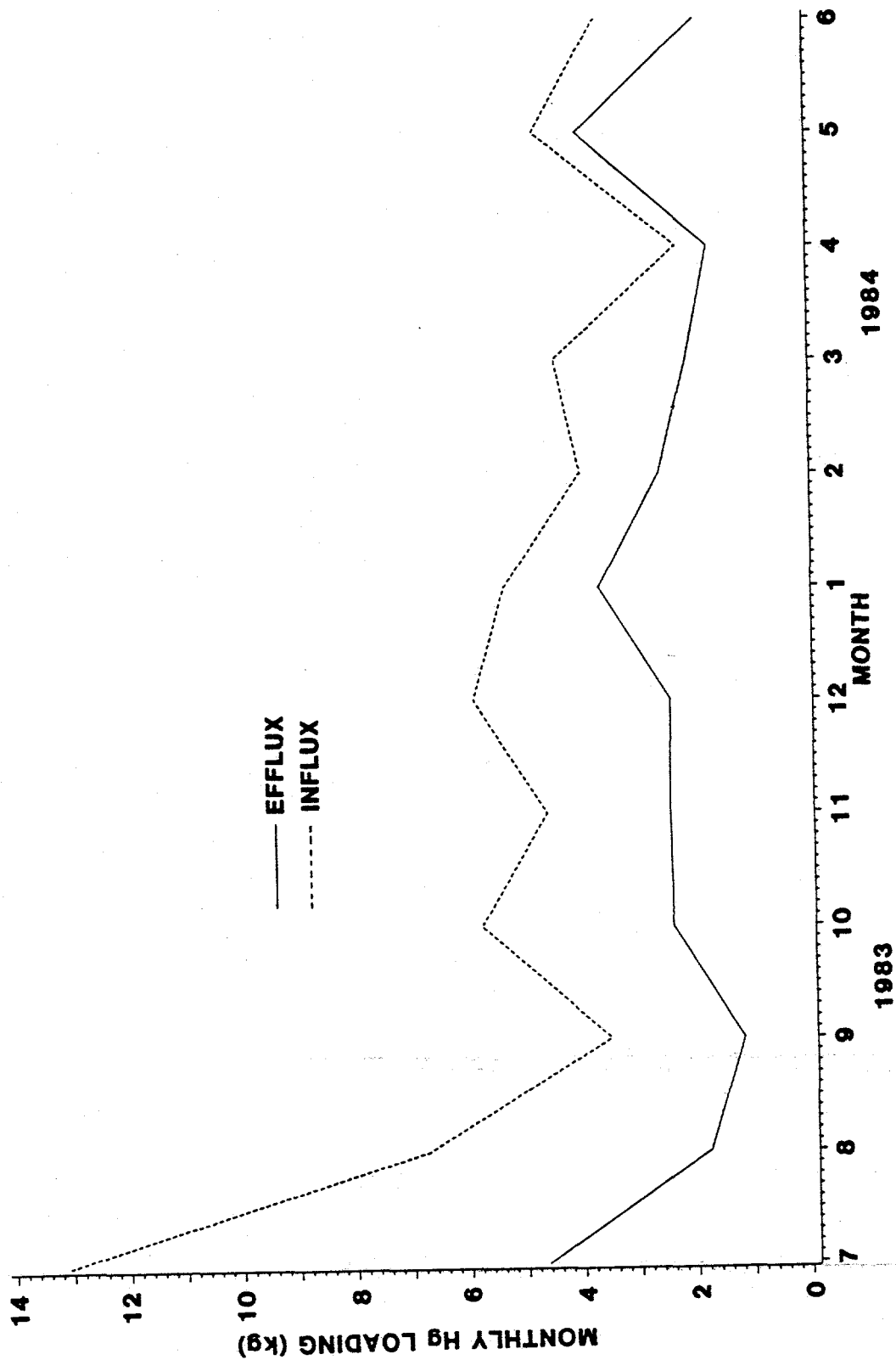
Fig. 3.2.2.   Monthly influx and efflux of mercury at NHP for the period
July 1983 through June 1984.

probably by-passed much of the pond volume. Total flow through the pond in May 1984 was also especially high compared with other months and may have further decreased the mercury trap efficiency. The relationship between total monthly flow and mercury trap efficiency is further illustrated in Fig. 3.2.3 which shows a weak correlation (r = 0.72, P <0.01) between these variables.

Overall the NHP data indicate that under steady state conditions (i.e., no plant upsets) approximately 4.6 kg of mercury is transported into the pond each month, with about 50% of this amount being retained by the pond in sediment deposits (see Fig. 3.2.4). The actual amount retained each month is likely to depend on several factors including total monthly flow, mercury loading and pond hydraulics (available pond volume and operational status of dispersion system). It should also be noted that not all of the mercury apparently retained by NHP necessarily remains in the bottom sediments. Formation and atmospheric emission of volatile dimethyl mercury in the organic-rich sediments contained in the pond may reduce the sediment inventory of mercury. The significance of this activity is unknown but is expected to be negligible in the overall mass balance.

3.3 Comprehensive Drain Surveys

Comprehensive sampling of selected discharge points has been carried out on several occasions since October 1982. There are over 250 numbered discharge points (see Y-12 Report YSE-44) within the Y-12 drainage system. Including tributaries to these trunk lines, there are easily over 1000 points where drainage water could be sampled. It has been difficult to
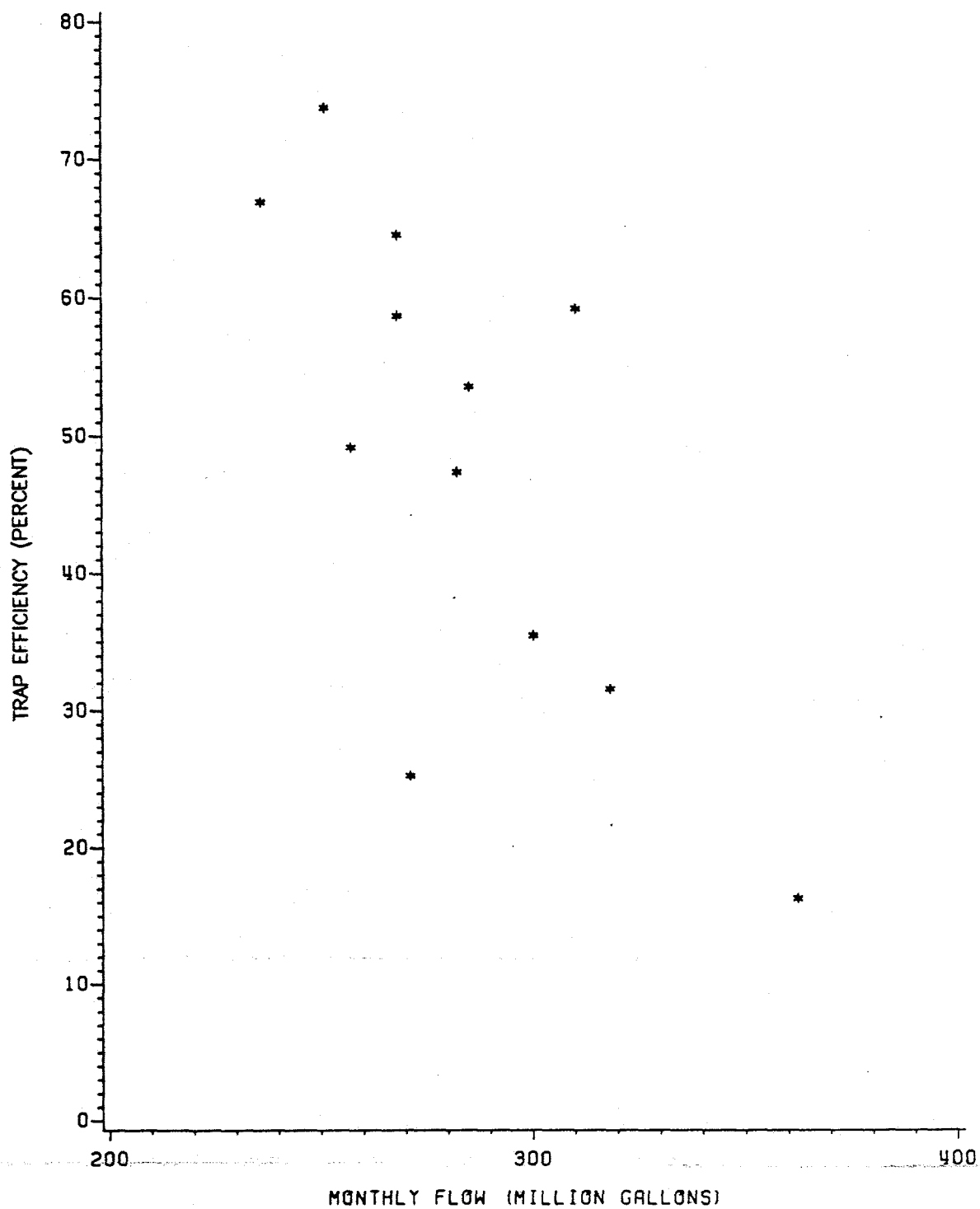
Fig. 3.2.3. Relationship between total monthly flow and mercury trap efficiency of NHP.

ORNL—DWG 85-1653

EFFLUX
2.3 kg/month

SEDIMENTATION
2.3 kg/month

INFLUX
4.6 kg/month
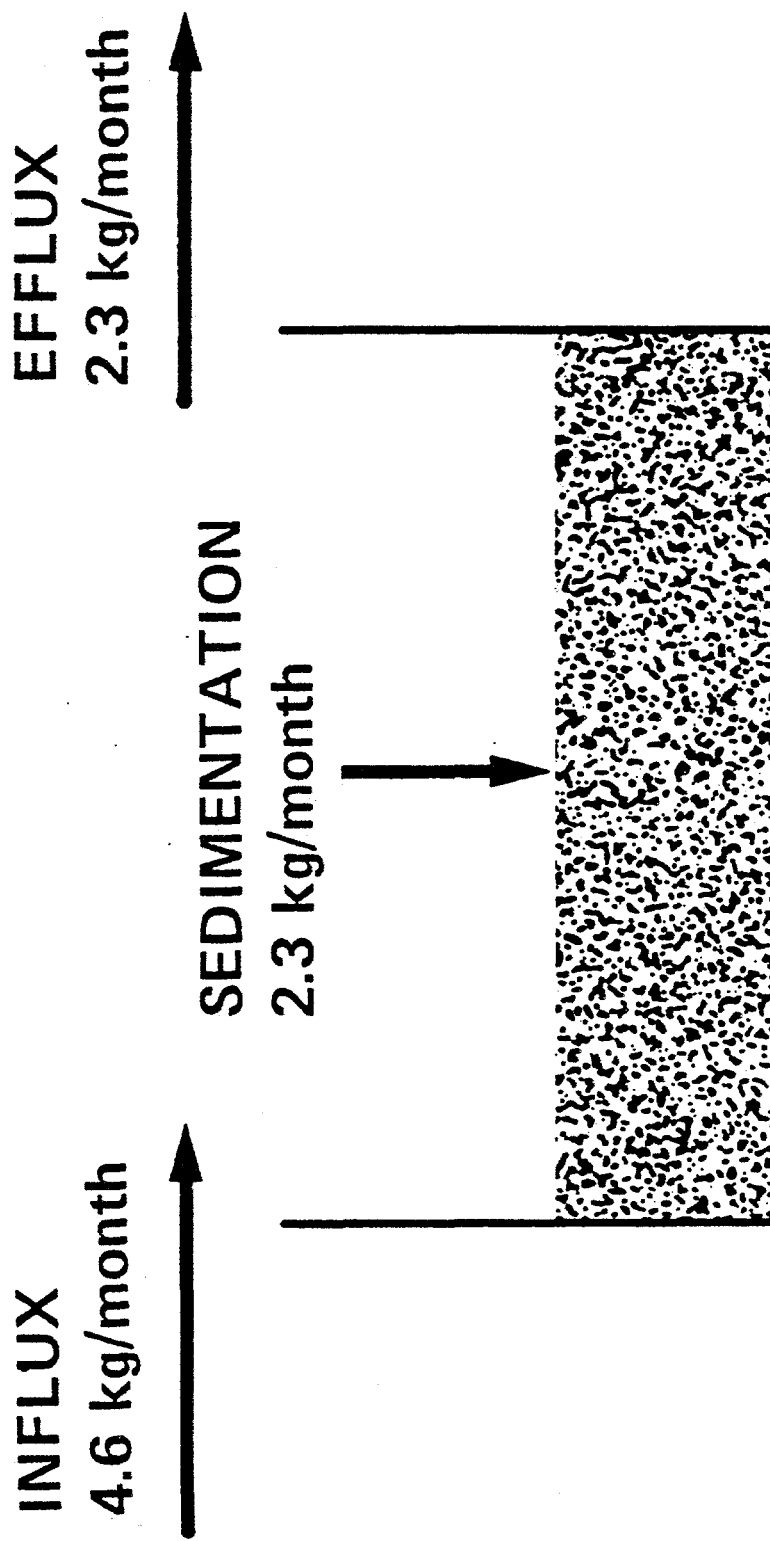
Fig. 3.2.4. Schematic of average mass balance of mercury at NHP.

sample more than a maximum of about 25 discharge points during one day, especially when flow measurements also had to be made. Access to the underground system in the western plant area (Figure 2.1.1), where much of the mercury originates, is very difficult and is complicated by the security barriers installed to forestall unauthorized entry into most of this system. Entry into manholes in this area has required coordination of personnel from Security, Utilities, Fire and Industrial Hygiene departments. Self-contained air supply has been required for entry into one manhole (SW9401-3/N). Despite these difficulties, all discharge points which are significant sources of drainage water for Upper East Fork Poplar Creek (open ditch) were sampled at least once. The main intent of the comprehensive surveys has been to identify areas yielding significant amounts of mercury to drainage water and to estimate the daily loading. Table 3.3.1 gives a summary of the dates, number of discharge points sampled and areas covered by the comprehensive surveys.

The first survey on October 28-29, 1982, involving only 10 locations, was carried out as a trial effort for the more comprehensive effort in December 1982. This survey also entailed evaluation of temporal variability of mercury concentration and loading (see Section 3.4), the trap efficiency of NHP for mercury (see Section 3.2) and the relationship, if any, between sources of mercury and sources of free chlorine (hypochlorite) and chloride ion. In this survey six samples were collected at each location over a 24-hour weekday period. Results are summarized by location in Table 3.3.2. Among the discharge points sampled upstream

Table 3.3.1. Inventory of comprehensive sampling of
discharge points

Inclusive Dates	Number of Discharge Points Sampled	Area Covered
October 28-29, 1982	10	Industrial ditch and Western Exclusion Area
December 9-10, 1982	48	"
June 5-9, 1983	13	"
July 17-August 23, 1983*	40	"
November 17-December 21, 1983	93	Western exclusion area only

*Investigation carried out by others (See Y-12 Report YSE-44)

Table 3.3.2. Summary of results of comprehensive sampling of selected
discharge points conducted October 28-29, 1982.
Values given are averages of six observations.

Location	Flow (L/s)	pH	Cond (µS/cm)	Temp (C°)	Cl	Cl$_2$	Hg (µg/L)	Hg Loading (g/d)
					(- mg/L -)			
NHP Outflow	366	7.3	342	20	17	0	2.1	67
NHP Inflow	366	7.4	333	21	14	0.05	4.0	127
667	18	7.5	260	24	9	1.1	0.4	0.6
910.4	22	7.1	241	23	7	1.2	0.1	0.2
915	2.7	7.4	248	20	6	1.2	30	6.6
170.8	29	7.6	244	28	8	0.74	0.2	0.4
E9811/N	55	8.2	490	25	9	0.36	2.9	14
SW9727-4/N	7.5	6.5	1220	26	101	0.05	17	5.9
SW9401-3/N[1]	22	6.7	272	27	–	0	15	28
NW9720-5/W	12	6.9	837	21	8	0	1.2	1.3

[1]One observation only.

of NHP, the following represented the most important as sources of mercury:

915   Origin in Bldg 9201-2
E9811/N   Main north-south trunk east of 9201-4
SW9727/N   Main north-south trunk center of 9201-4
SW9401-3/N   Main north-south trunk west of 9201-4

The three discharge points traceable to 9201-4 were expected to be important sources of mercury but collectively accounted for only 31% (40 g/day) of the total mercury loading to NHP (127 g/day). Discharge point 915, originating from Building 9201-2, accounted for an additional 5% of the total loading. Thus, less that 40% of the total loading to NHP could be accounted for based on this preliminary survey. The survey results also documented the presence of free chlorine and chloride in several discharges but did not demonstrate any consistent relationship between elevated mercury concentrations and chlorine or chloride. The temporal aspects of this preliminary survey are discussed in Section 3.4.

Complete results of the December 9-10, 1982, survey are tabulated in Appendix A and summarized in Table 3.3.3. The 12 discharge points representing specific buildings (eg. Building 9201-2) or areas (e.g., E9811/N representing the main trunkline [48" pipe] running between 9201-4 and 9204-2) account for 138 g/d total loading to the industrial ditch. This value is remarkably consistent with the NHP inflow loading values (125 and 167 g/d) measured on December 9 and December 10.

As shown in Table 3.3.3, 42% (58.1 g/d) of the total mercury loading to the industrial ditch was originating west of Building 9201-5,

Table 3.3.3. Summary of Hg loadings by building/area for survey
of December 9-10, 1982.

Building/Area	Discharge Points	Hg Loading (g/d)	Upstream Tributaries	Hg Loading (g/d)
9201-2	909.4(47)	1.0		
	910.4(48)	0.5		
	915(49)	8.6		
	935.6(51)	2.5		
	980.5(55)	2.3		
	1062.1	<0.1		
			NE9201-4/N	<0.4
East 9201-4	E9811/N(150)	14.4	N9720-3	0.2
			SW9204-2/W	4.6
Center 9201-4	SW9401/N(160)	3.5		
			SW9201-4/E	0.4
			SW9201-4/N	14.6
West 9201-4	SW9401-3/N(163)	26.6	SW9201-4/NE	2.5
			SW9201-4/N	0.6
Center 9201-5	NE9720-5/N	14.7	S9201-5/E	0.2
			S9201-5/N	14.5
West 9201-5	NE9720-5/NW	58.1	SW9976/N	0.6
			SW9976/NW	54.6
West 9204-4	NW9720-5/W	5.1	SW9204-4/N	0.01
			SW9204-4/NE	0.4
81-10 Area[1]	1719S	30	Center 9201-5	14.7
			NW9720-5/NW	58.1
			SW9720-5W	9.9

Total	168
NHP Inflow (12/9/82)	125
NHP Inflow (12/10/82)	167

[1] Not sampled, used down stream discharge (116 g/d) less upstream
tributaries (14.7 g/d + 58.1 g/d + 9.9 g/d)

ie., either from the western end of 9201-5 or the eastern end of 9204-4.
Analyses from upstream tributaries during this survey do not resolve the
sources of this high loading. Building 9201-4 contributed about 32% of the
total mercury loading, if it can be assumed that discharge points E9811/N,
SW9727-4/N and SW9401-3/N all represent drainage from Building 9201-4. The
analyses of upstream tributaries generally supported this assumption.
Building 9201-5 contributed at least 11% of the total loading and Building
9201-2 contributed another 11% of the total. The additional discharge
points not shown in Table 3.3.3, such as 1312(109) and 667(21), contributed
less than 5% of the total loading. Discharge point 1312(109) serves the
9733 building complex (known mercury spill), while point 667(21) was
receiving plant laundry discharge in December 1982 (subsequently
discontinued).

The December 9-10 survey confirmed that all buildings where mercury had
been formerly used or spilled should be suspected as sources of mercury to
drainage water. The major surprise was that Building 9201-4, which had not
been stripped of Hg-contaminated equipment, was not apparently the most
important source of mercury. The survey data clearly implicated Buildings
9201-5 and 9204-4 as the most important sources. Building 9201-5 was
stripped of all Hg-contaminated equipment in 1966. Building 9204-4, which
originally contained the ELEX production plant, was stripped and
decontaminated in 1957.

The next comprehensive survey of mercury in plant drainage waters
was conducted June 5-9, 1983. This proved to be an atypical period with

regard to mercury losses (Table 3.3.4), but the survey results alerted

mercury clean-up personnel to the consequences of some of their activities.

Prior to and during this period, a concerted effort was being made to

reduce drainage water losses of mercury by cleaning metallic mercury which

had accumulated in basement sumps in Buildings 9201-4 and 9201-5.

Initially the sumps were dewatered by simply pumping into the nearest storm

drain. At the time this seemed to be appropriate because the permanent

sump pumps accomplished the same thing on an intermittent basis.

Unfortunately the dewatering pumps resuspended particulate mercury in the

sumps and greatly elevated mercury concentrations and loadings in the

downstream drainage system. During the 5 day sampling period, NHP inflow

mercury loading varied from 29 to 2100 g/d (Table 3.3.4), but only an

insignificant amount of rainfall (<0.10 inches) occurred. Based on earlier

mercury loading values, 5 of the 14 locations sampled during this survey

were being affected by clean-up activities. The locations are:

> E9811/N (150)
> SW9201-4/N
> 1719N (C-2)
> NHP Inflow
> NHP Outflow

Table 3.3.5 summarizes mercury loading values by area for the sampling

locations not affected by clean-up activities. As indicated by some of the

duplicate measurements (on adjacent days), variability in mercury loading

from day to day was fairly high. Nonetheless, these loadings generally

agreed within a factor of 2 with each other and with earlier observed

values for the same locations. The importance of the area west of Building

9201-5 as a souce of mercury was again evident by the high loading observed

(61 and 30 g/d) for discharge point NE9720-5/NW.

Table 3.3.4. Results of Y-12 drain survey conducted June 1983

Location	Date	Time	Flow (L/S)	Hg (µg/L)	Hg Loading (g/d)
E9811/N	09JUN83	9:15	53.618	43.00	199.20
E9811/N	09JUN83	9:45	44.977	58.00	225.39
NE9720-5/N	09JUN83	10:45	4.709	12.00	4.88
NE9720-5/NW	08JUN83	10:50	35.219	20.00	60.86
NE9720-5/NW	09JUN83	10:45	31.833	11.00	30.25
NHP INFLOW	05JUN83	9:28	353.179	10.00	305.15
NHP INFLOW	05JUN83	19:21	341.070	11.00	324.15
NHP INFLOW	06JUN83	10:15	353.179	69.00	2105.5
NHP INFLOW	06JUN83	19:15	377.814	23.00	750.79
NHP INFLOW	07JUN83	9:58	341.070	20.00	589.37
NHP INFLOW	08JUN83	9:00	329.104	10.00	284.35
NHP INFLOW	08JUN83	19:25	341.070	1.00	29.47
NHP INFLOW	09JUN83	9:00	329.104	12.00	341.21
NHP INFLOW	09JUN83	19:00	341.070	21.00	618.84
NHP OUTFLOW	05JUN83	9:37	353.179	4.00	122.06
NHP OUTFLOW	05JUN83	19:29	341.070	4.00	117.87
NHP OUTFLOW	06JUN83	10:15	353.179	4.00	122.06
NHP OUTFLOW	06JUN83	19:05	377.814	5.00	163.22
NHP OUTFLOW	07JUN83	9:58	341.070	3.00	88.41
NHP OUTFLOW	08JUN83	9:00	329.104	3.00	85.30
NHP OUTFLOW	08JUN83	19:30	341.070	14.00	412.56
NHP OUTFLOW	09JUN83	9:00	329.104	4.00	113.74
NHP OUTFLOW	09JUN83	19:10	341.070	12.00	353.62
SE9720-5/W	08JUN83	10:37	15.437	<1.00	<1.33
SE9720-5/W	09JUN83	10:30	18.520	1.00	1.60
SW9201-4/E	08JUN83	12:30	0.030	530	1.37
SW9201-4/E	09JUN83	12:55	0.030	67.00	0.17
SW9201-4/N	08JUN83	12:30	5.354	160	74.01
SW9201-4/N	08JUN83	12:30	6.834	7.00	4.13
SW9201-4/N	09JUN83	12:55	5.354	150	69.38
SW9201-4/N	09JUN83	12:55	5.384	8.00	3.72
SW9201-4/NE	08JUN83	12:30	0.030	940	2.44
SW9201-4/NE	09JUN83	12:55	0.030	980	2.54
SW9727-4/N	08JUN83	13:00	4.585	8.00	3.17
SW9727-4/N	09JUN83	11:20	7.012	10.00	6.06
1719N	05JUN83	9:12	137.397	45.00	534.20
1719N	06JUN83	9:05	116.336	40.00	402.06
1719N	06JUN83	19:30	81.435	62.00	436.23
1719N	07JUN83	9:20	108.581	93.00	872.47
1719N	08JUN83	9:00	89.123	120	924.02
1719N	08JUN83	19:05	107.392	52.00	482.49
1719N	09JUN83	9:15	75.911	41.00	268.91
1719N	09JUN83	19:20	117.437	16.00	162.35
1719S	05JUN83	9:07	43.329	10.00	37.44

Table 3.3.4 (Continued)

Location	Date	Time	Flow (L/S)	Hg (µg/L)	Hg Loading (g/d)
1719S	06JUN83	9:00	80.961	22.00	153.89
1719S	06JUN83	19:30	68.549	7.00	41.46
1719S	07JUN83	9:20	38.801	16.00	53.64
1719S	08JUN83	9:00	28.653	21.00	51.99
1719S	08JUN83	19:00	31.860	17.00	46.80
1719S	09JUN83	9:15	31.860	15.00	41.29
1719S	09JUN83	19:30	36.405	43.00	135.25
915	08JUN83	13:30	2.867	18.00	4.46
915	09JUN83	13:40	10.1923	17.00	14.97

Table 3.3.5. Summary of Hg loadings by building/area for
survey of June 5-9, 1983

Building/Area	Discharge Point	Hg Loading (g/d)	Upstream Tributaries	Hg Loading (g/d)
9201-2	915(49)	4.5,15		
Center 9201-4	SW9727-4	3.2,6.1		
West 9201-4	SW9401-3/N(163)	$-^1$	SW9201-4/E SW9201-4/W SW9201-4/NE	1.4,0.2 4.1,3.7 2.4,2.5
Center 9201-5	NE9720-5/N	7.8,4.9		
West 9201-5	NE9720-5/NW	61,30		
West 9204-4	SE9720-5/W^2	<1.3,1.6		

[1]Not sampled
[2]May include small component of drainage from NE9720-5/NW

The comprehensive survey conducted between November 17, 1983 and December 21, 1983 was actually a series of six surveys covering limited areas in the Western Exclusion Area (see Appendix A for complete data listing). These smaller surveys were oriented towards tracing each main north-south trunkline upstream as far as possible. The six trunklines are represented downstream by the following locations:

E9811	NE9720-5/N
SW9727-4	NE9720-5/NW
SW9401-3	NW9720-5/W

In the following discussion, survey data are presented as a group of drainage diagrams with discharge, mercury concentration, and mercury loading presented on separate figures. It is important to keep in mind that the displayed values were not measured simultaneously, often not even on the same day. Thus, mass balance for water and mercury should not necessarily be expected. Also, as discussed in the methods section, discharge measurements are subject to considerable uncertainty ($\pm 50\%$) and may have led to some of the poor balance for water and mercury in some cases.

E9811 This 48" trunkline serves the west end of Building 9204-2 and the east end of Building 9201-4, as well as a group of buildings located north of 9204-2. Figures 3.3.1 through 3.3.3 display the discharge, mercury concentration, and mercury loading values, respectively, for this trunkline and its tributaries. Rainfall occurred during a portion of the sampling of

this area on December 14 and thus discharge values especially at SE9201-4 are poorly balanced (Figure 3.3.1). Nonetheless the discharge data reveal that most of the flow on this line originates north of the permanent monitoring station at NE9201-4. The mercury concentration data show an especially high value (71 µg/L) for the line running eastward along the south outside wall of Building 9201.4 (Figure 3.3.2). Even with the relatively low flow (0.8 L/S) in this line, the mercury loading still amounts to 4.9 g/d (Figure 3.3.3). One sample down stream of this pipe showed considerably elevated flow (110 vs. 48 l/sec) and mercury concentration (7.8 vs. 2.4 µg/l) when compared to data further downstream. Possible explanations for this are that it had rained 0.05" within one half hour of taking the sample and roof downspout runoff had flowed down this line resuspending some of the mercury in the line, and/or a pump had come on discharging water into this line at the time of the downstream sampling. An additional significant source of mercury also appears to exist upstream of the northeast corner of Building 9201-4. The line orginating north of this point (ie. SE9723-18/N) carried 3 L/sec. of drainage waters with 11 µg Hg/L and thus accounts for a 2.8 g/d mercury loading. Sources of mercury upstream of this measuring point were not expected nor investigated.

The results of this trunkline survey indicate that although Building 9201-4 may contribute as much as 50% of the mercury loading to this line, other sources may exist north or northeast of 9201-4. Mercury beads and small puddles were observed in most of the manholes along this trunkline.

ORNL-DWG 85-1634

DISCHARGE (L/s)
DECEMBER 14-15, 1983

9201-4

<0.1
<0.1
1.3
3
3.5
4.7
29
84
1.9
60
0.8
110 *
1.2
48

* 0.05" RAIN PRIOR
TO SAMPLE
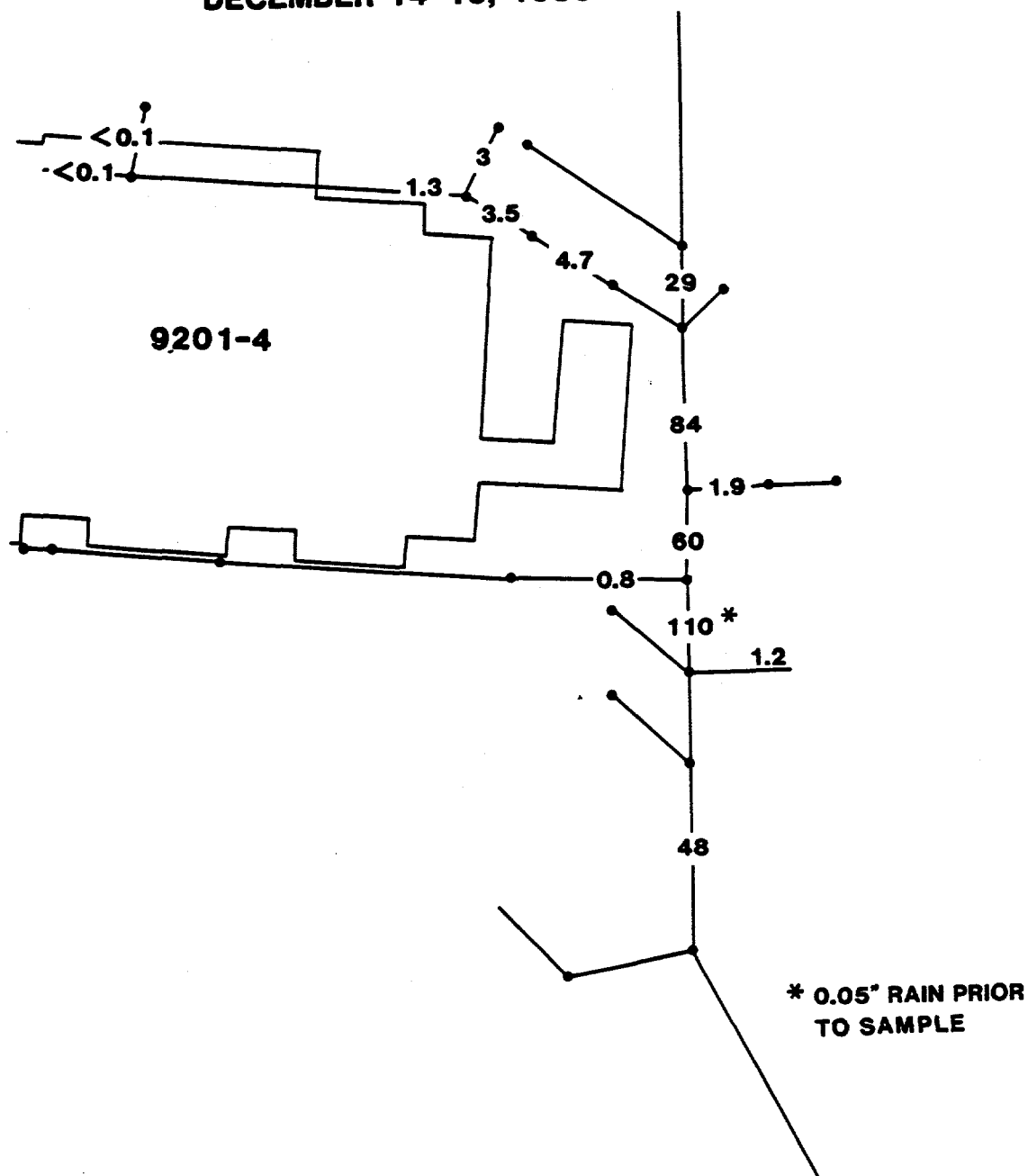
EAST OF 9201-4

Fig. 3.3.1. Instantaneous discharge values for sampling points east
of 9201-4.

Hg CONCENTRATION (µg/L)
DECEMBER 14-15, 1983

3.5

- 2.4   1.8   11

8.0

3.0   <0.5

9201-4

0.5

-2.9

0.6

71

7.8

<0.5

2.4

≤0.5
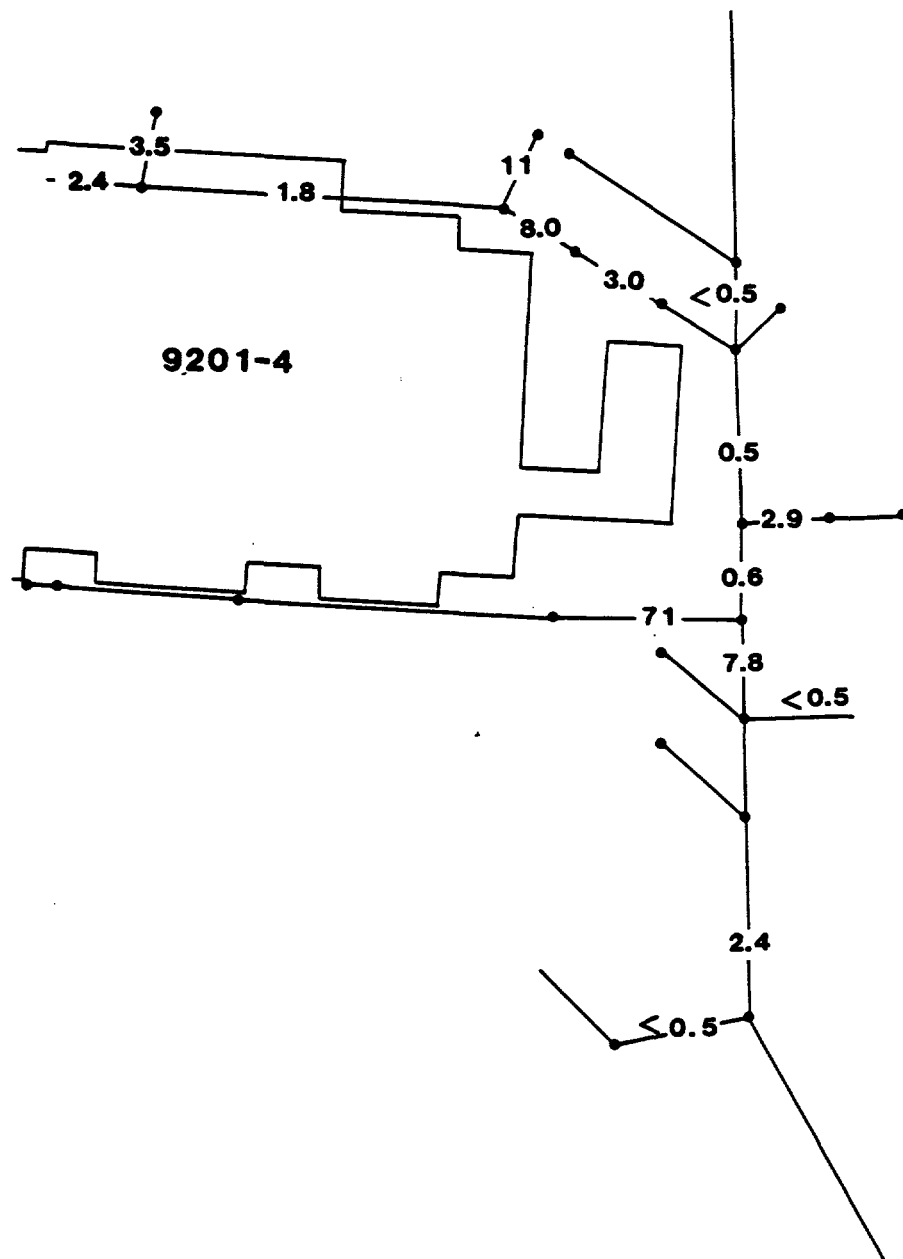
EAST OF 9201-4

Fig. 3.3.2. Mercury concentrations for sampling points east of 9201-4.

Hg LOADING (g/d)
DECEMBER 14-15, 1983
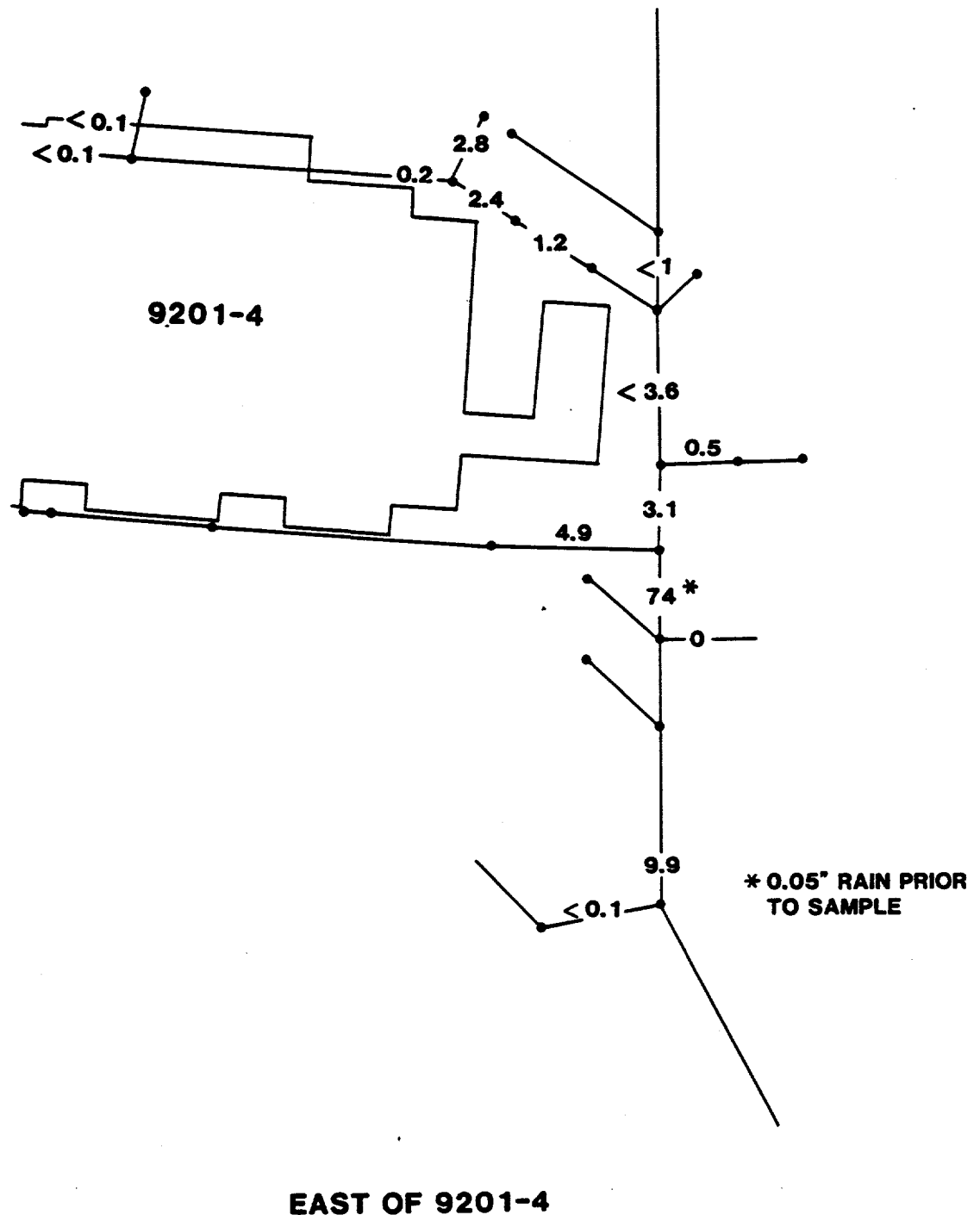
EAST OF 9201-4

Fig. 3.3.3. Mercury loadings for sampling points east of 9201-4.

SW9727-4 This 36" trunkline serves the south center of Building 9201-4, including part of the Y-12 Steam Plant. Figures 3.3.4 through 3.3.6 display the discharge, mercury concentration, and mercury loading values, respectively, for this trunkline and some of its tributaries. While sampling this trunkline at SW9227-4, discharge and mercury concentration varied considerably over a very short period (<30 min.), apparently due to backwashing of the water treatment system at the steam plant. As shown in Figure 3.3.4, most of the flow in this line originates form the tributary at N9727-3. Mercury concentrations (Figure 3.3.5) in this subsystem vary greatly, from a high of 610 µg/L to a low of <0.5 µg/L. The higher mercury concentrations are associated with points of very low flow and thus mercury loadings for these points are low. Some metallic mercury was evident in some of the manholes associated with this subsystem.

SW9401-3 This 36" trunkline serves the west end of Building 9201-4 and the east end of Building 9201-5, as well as a group of buildings located north of Building 9201-5 (e.g., 9103, 9723-19, 9723-21). Figures 3.3.7 through 3.3.9 display the discharge, mercury concentration, and mercury loading values, respectively, for this trunkline and its tributaries. A substantial fraction of the flow (Figure 3.3.7) on this line originates from the tributary at NW9401-3. This is apparently water from the steam plant which is low in mercury (Figures 3.3.8 and 3.3.9). The west tributary at SW9201-4 contributed the next most significant amount of water. At the time of sampling this tributary was contributing only about 2 g/d of mercury to the trunkline but an upstream measurement at another time indicated that much high mercury loading was possible for this

DISCHARGE (L/s)
DECEMBER 8, 1983

9201-4

< 0.1

←< 0.1

3.3

< 0.1

1.4

─16 ─*

18
55
39

*ESTIMATED FROM FLOW
MEASUREMENTS TAKEN IN
OCTOBER 1983

CENTER OF 9201-4

Fig. 3.3.4. Instantaneous discharge values for sampling points located
south (center) of 9201-4.

Hg CONCENTRATION (µg/L)
DECEMBER 8, 1983

9201-4

610

14

5

< 0.5

18

5.6

1.6
3.6
2.8
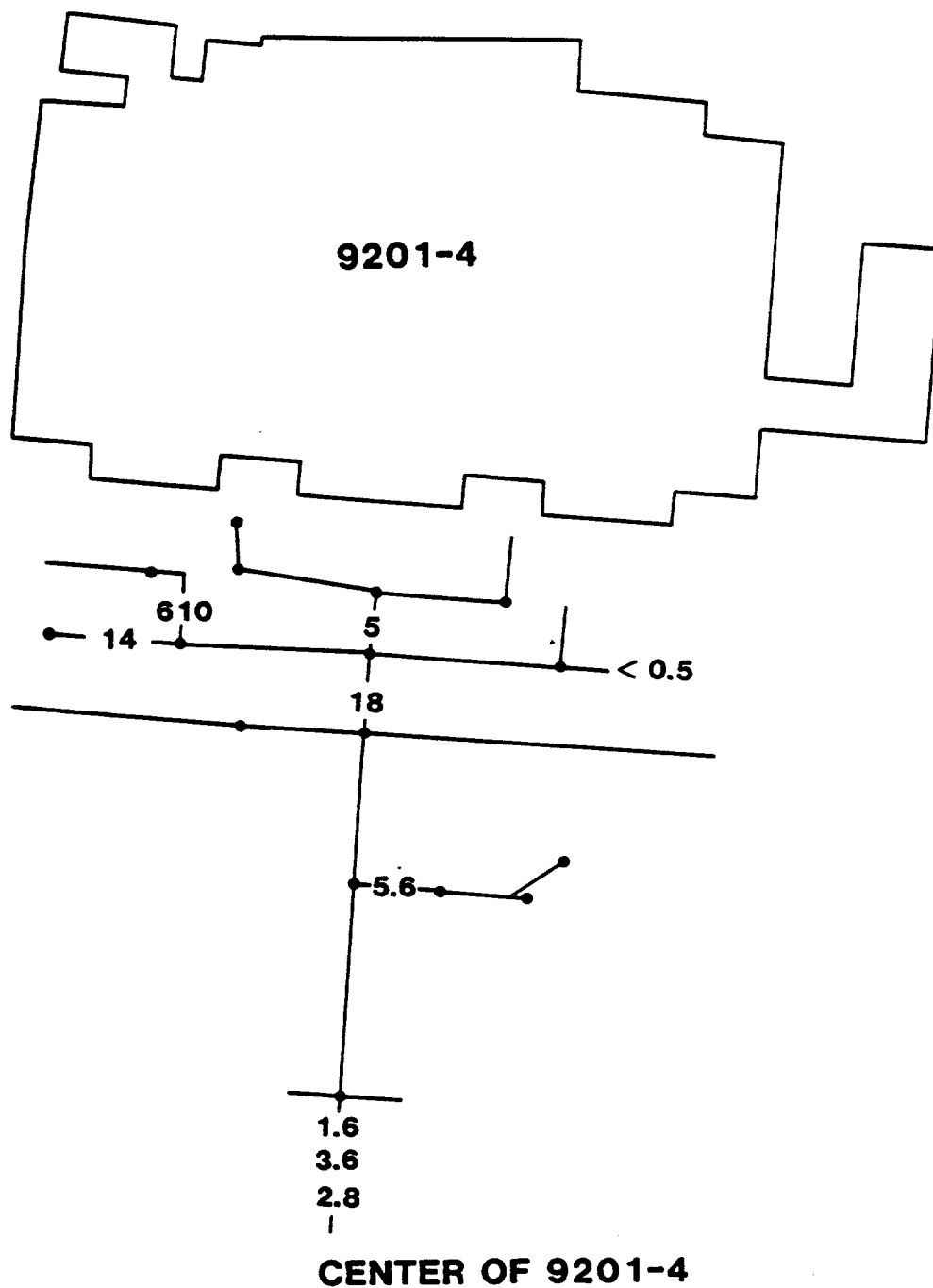
CENTER OF 9201-4

Fig. 3.3.5. Mercury concentrations for sampling points located south
(center) of 9201-4.

Hg LOADING (g/d)
DECEMBER 8, 1983)

9201-4

0.3

1.5

<0.1   <0.1

2.1

8

2.5
17
9.4
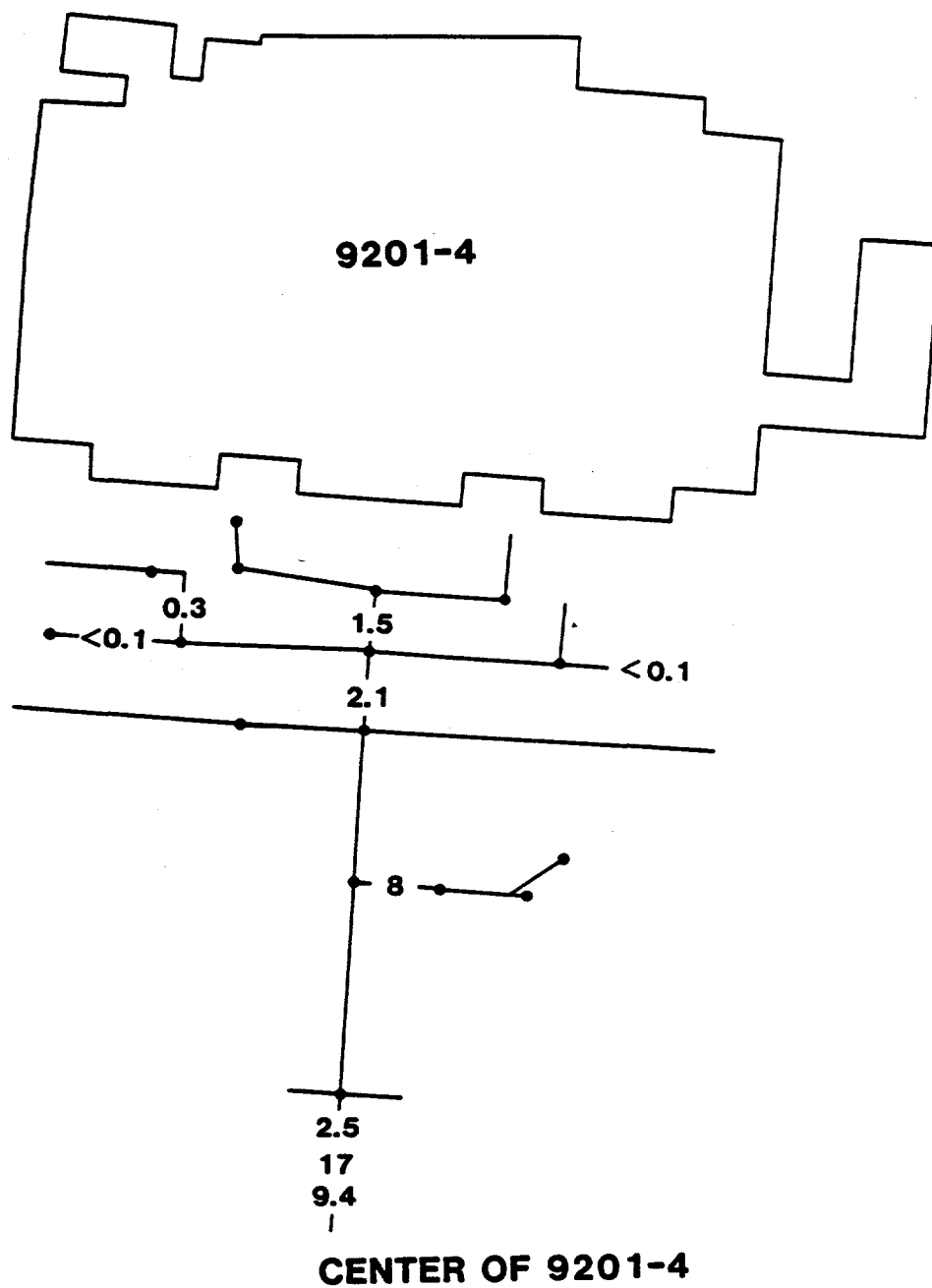
CENTER OF 9201-4

Fig. 3.3.6. Mercury loadings for sampling points located south
(center) of 9201-4.

DISCHARGE (L/s)
DECEMBER 1, 7-8, 1983

< 0.1

< 0.1

< 0.1

< 0.1

< 0.1

1.9

1.8

5.4

3.8

9201-5

9201-4

0.2

0.1

5.7

6.4

6.4 — 1.5

6.7

0.1

0.3

0.2

15

—< 0.1 — 10 —

WEST OF 9201-4

Fig. 3.3.7. Instantaneous discharge values for sampling points located
west of 9201-4.

Hg CONCENTRATION (µg/L)
DECEMBER 1, 7-8, 1983

10

1.5

41

< 0.5   5.7

0.6

150

31

35   1.2

9201-5

9201-4

20

26

36

37

37—15   3.6   440   32

61

23

4   < 0.5

WEST OF 9201-4

Fig. 3.3.8.   Mercury concentrations for sampling points located west of 9201-4.

Hg LOADING (g/d)
DECEMBER 1, 7-8, 1983

<0.1

0

<0.1

0.1

0

0.1

25

4.8

0.5

11

9201-5

9201-4

0.4

0.3

18

3.3

21

21—1.9

2.1

1.0

32

1.1

30.5

0

<0.4
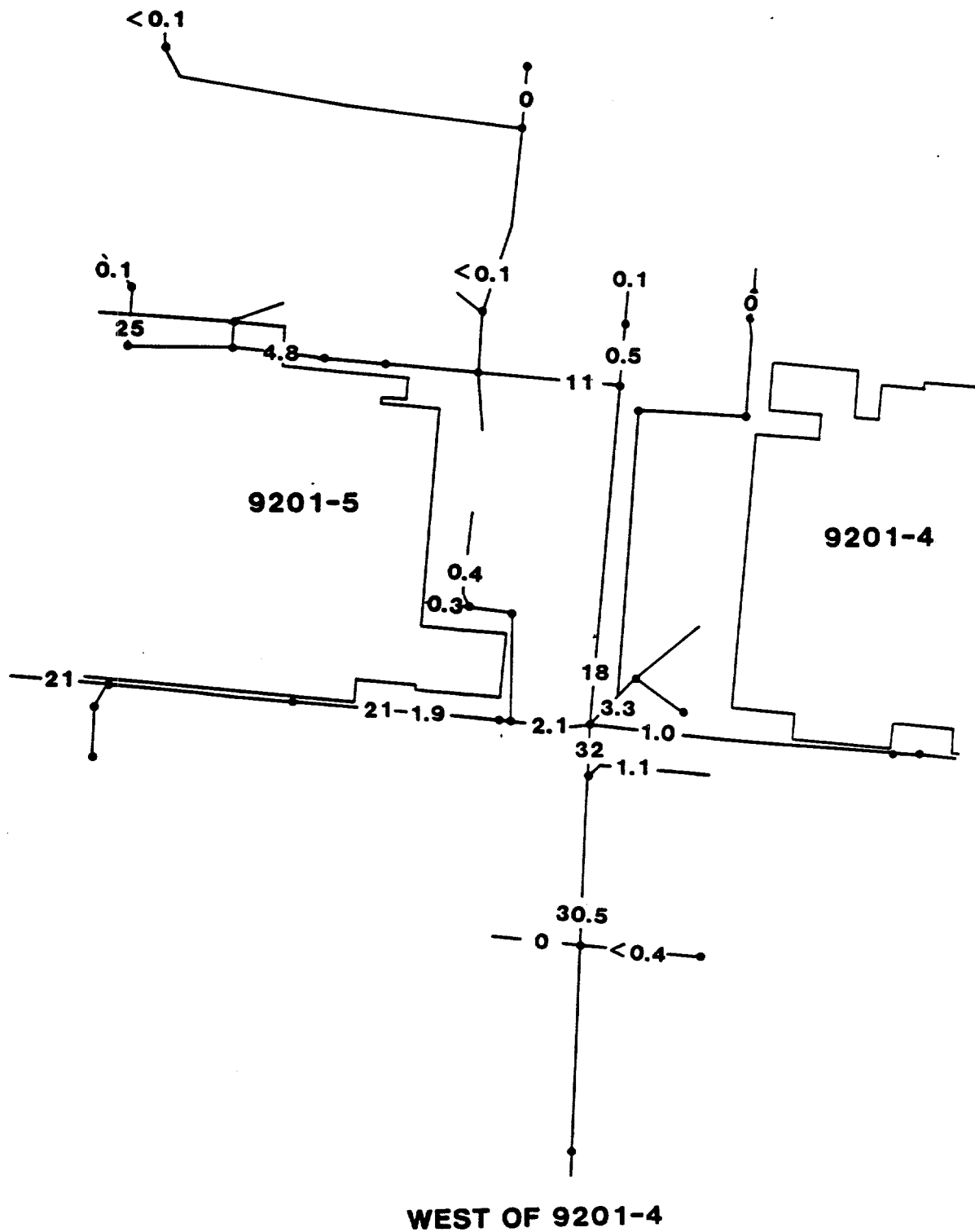
WEST OF 9201-4

Fig. 3.3.9. Mercury loadings for sampling points located west of 9201-4.

tributary. Moderately high mercury concentrations associated with low flows were present in pipes all around the margin of Building 9201-5 and around the southwest corner of Building 9201-4. High mercury concentration (35 µg/L) and loading (11 g/d) also occured in the west pipe at S9711-6/3. This loading represents about one-third of the total for this trunkline and originates mainly from the north side of Building 9201-5. Elevated mercury concentrations (10 and 1.5 µg/L) were detected in drainage water near Building 9103 but the loading from this area is not significant (ie. <1g/d). Building 9103 was constructed very near to, or over, the site used for mercury deflasking in the 1950's.

NE9720-5 This 36" trunkline serves the south center of Building 9201-5. Figures 3.3.10 through 3.3.12 display the discharge, mercury concentration and mercury loading values, respectively, for this trunkline and its tributaries. As shown by Figure 3.3.10, discharge at NE9720-5 greatly exceeded discharge at upstream point S9201-5. Discharge values for these two points were measured on November 7 and November 24, respectively, and thus should not be expected to agree. Also the north pipe at S9201-5 has shown large fluctuations in flow during sampling. For example, on November 24 flow increased from 1.8 L/s to 7.0 L/s within a 15-minute period. At the same time mercury concentration increased from 16 µg/L to 75 µg/L and mercury loading increased from 2.4 g/d to 45 g/d. The mercury concentration and loading graphs (Figures 3.3.11 and 3.3.12) clearly show that the main source of mercury on this trunkline is located on the tributary represented by the north pipe at S9201-5 and that this is a highly variable source. Some metallic mercury was visible in all of the manholes on this line.

DISCHARGE (L/s)
NOVEMBER 17, 23,-24, 1983

9201-5

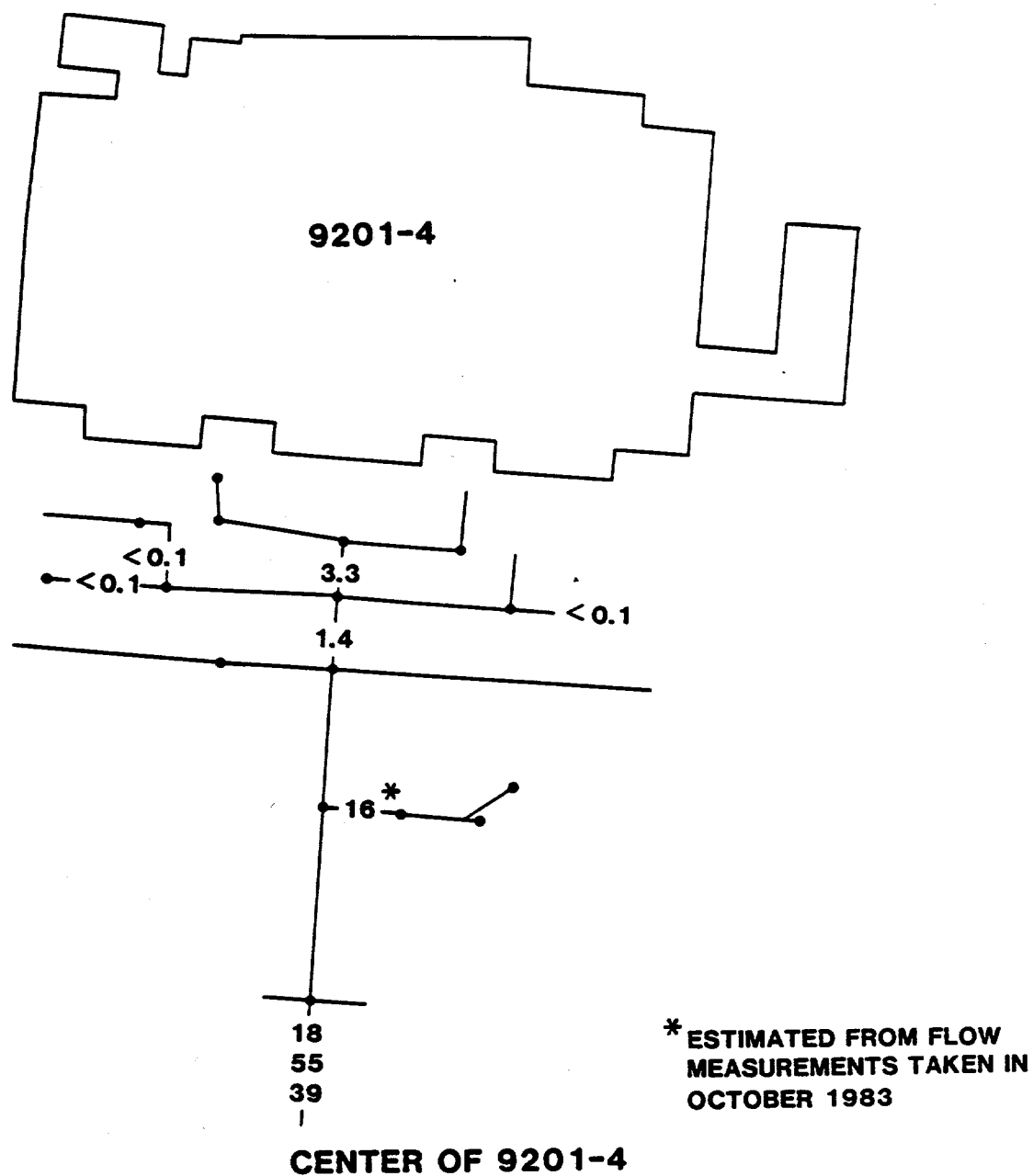0.1 ⌐ 0.3
1.2
0.1 ┤
1.8
7.0
4.5 ┴ 0.6
0.3
2.7
2.2

36
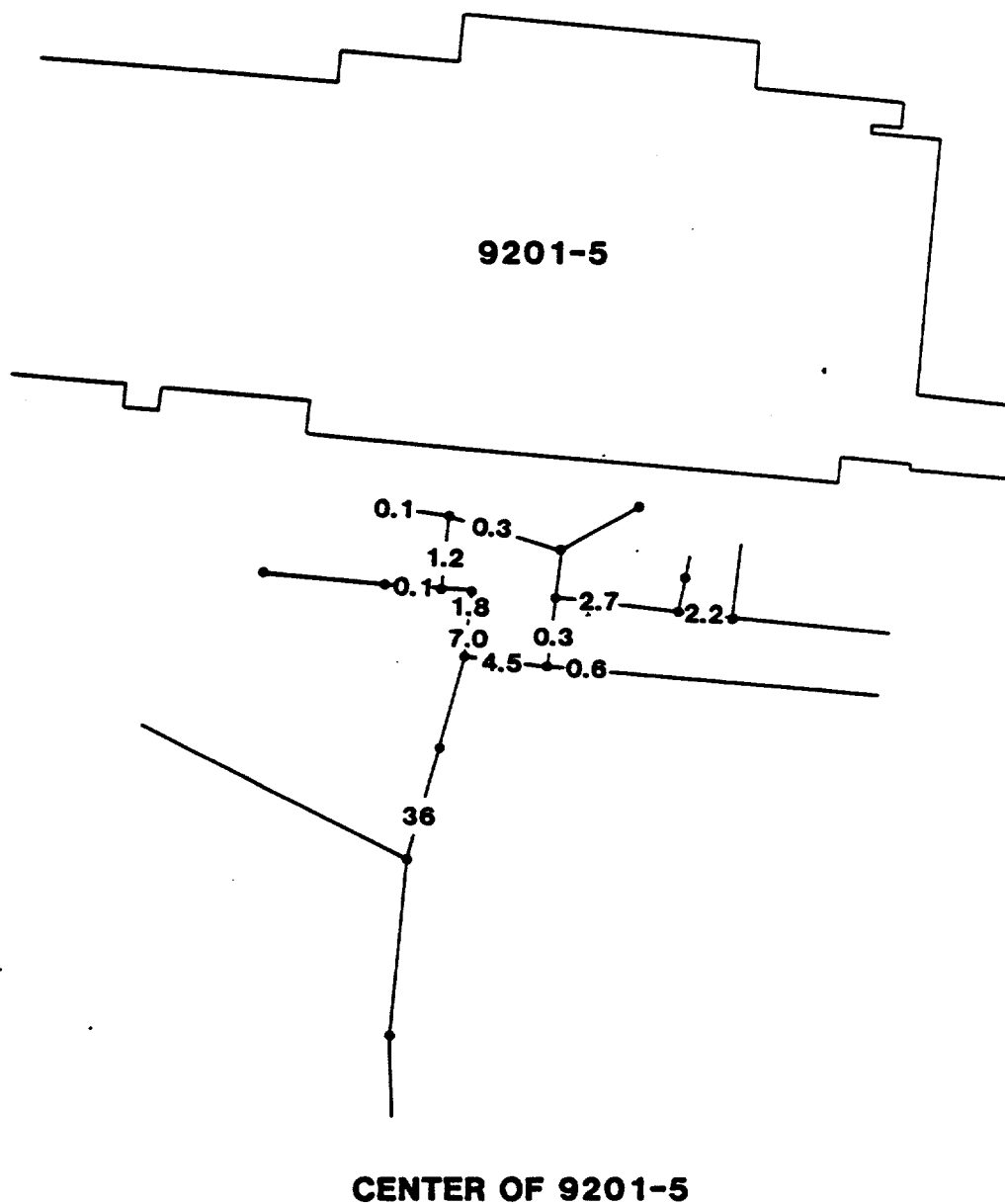
CENTER OF 9201-5

Fig. 3.3.10. Instantaneous discharge values for sampling points
located south (center) of 9201-5.

**Hg CONCENTRATION (µg/L)
NOVEMBER 17, 23-24, 1983**

9201-5

<1 5
150
76 16
75
1.0 <1
3
<1 <1

1
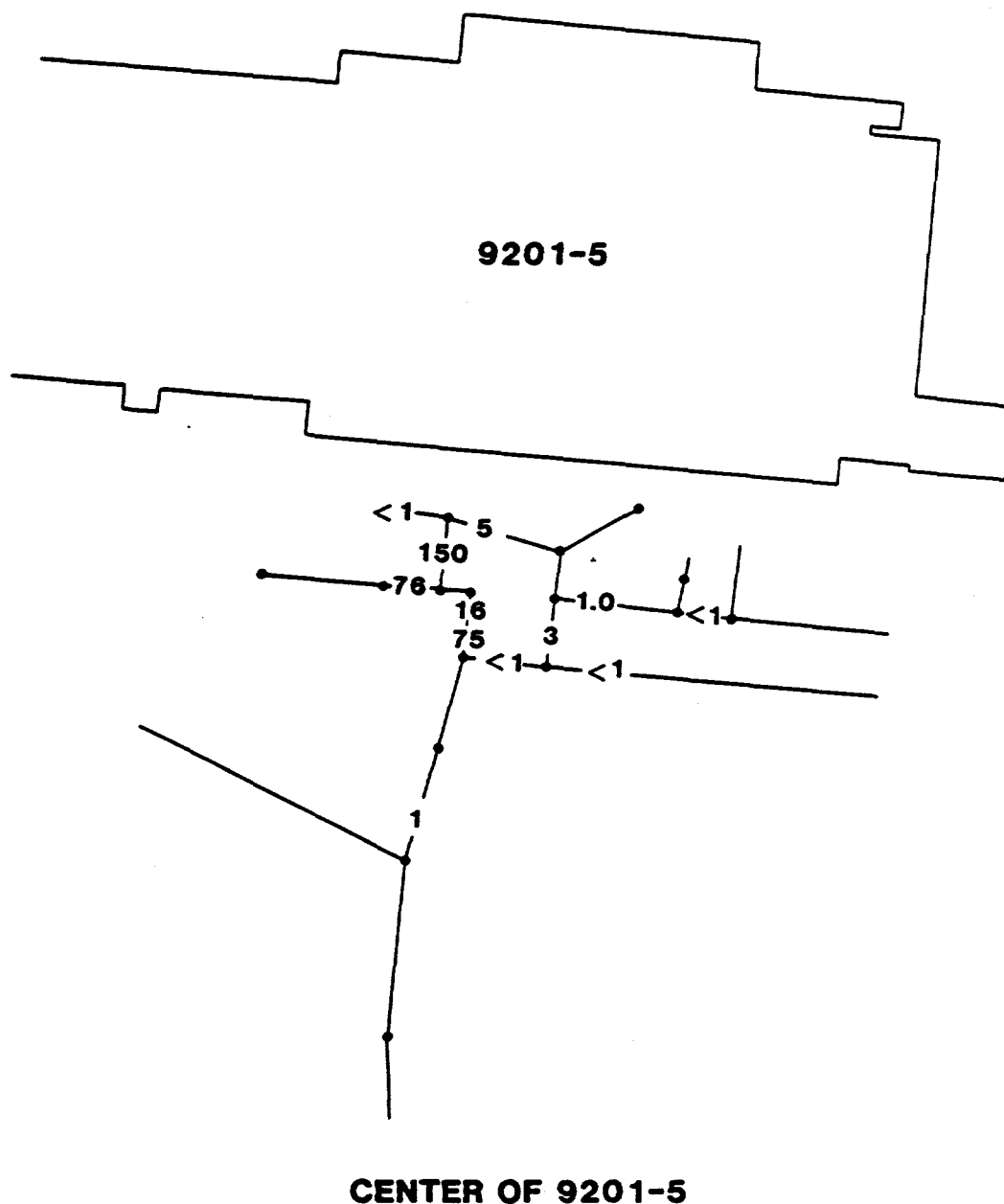
CENTER OF 9201-5

Fig. 3.3.11. Mercury concentrations for sampling points located south
(center) of 9201-5.

Hg LOADING (g/d)
NOVEMBER 17, 23-24, 1983

9201-5

<1.0 ┬ 0.1
15
●─────0.4┤
2.4 ┬ 0.2
45 0.8 ┬ <0.2
<0.4┴ <0.1

3.1
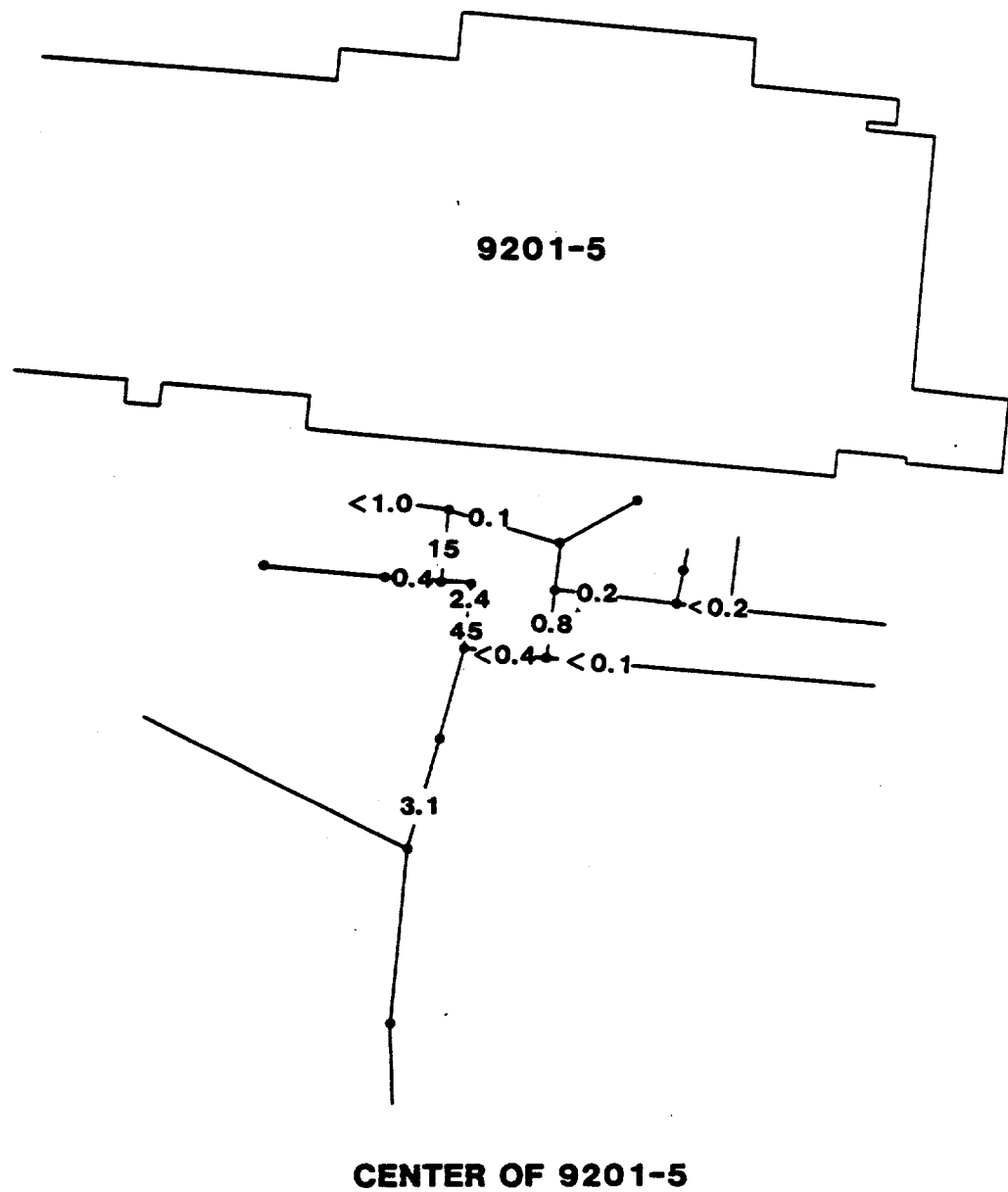
CENTER OF 9201-5

Fig. 3.3.12. Mercury loadings for sampling points located south
(center) of 9201-5.

<u>NE9720-5NW</u> This 48" trunkline serves the west end of Building 9201-5

and the east end of Building 9204-4, as well as some buidings and areas

to the north cf 9201-5 and 9204-4. Figures 3.3.13 through 3.3.16 display

the discharge, mercury concentration and mercury loading values for this

trunkline and its tributaries. The discharge graph (Figure 3.13.13) shows

that most of the flow in this trunkline originates at a pipe emanating from

the south center of Building 9204-4. Additional significant sources of

flow occur near the southwest corner of Building 9201-5 and near, or

upstream, of the northwest corner of Building 9201-5. Except for a high

mercury concentration value in a pipe southwest of Building 9103, the

highest mercury concentrations occur in the pipes south of Building 9204-4.

In terms of mercury loading (Figure 3.3.15), the pipe emanating from the

south center of Building 9204-4 is by far the dominant source of mercury in

this subsystem and in the entire plant. This pipe is also apparently quite

variable (see subsequent discussion in Section 3.4) as evidenced by the

lower loadings measured earlier on the same day at downstream points. Note

also that the December 9-10, 1982, and June 5-9, 1983 surveys showed

mercury loadings ranging from 30 to 61 g/d for this area.

<u>NW9720-5/N</u> This 60" trunkline serves the west end of Building 9204-4 and

the plant area west to the hydrologic divide with Bear Creek.

Figures 3.3.16 through 3.3.18 display the discharge, mercury

concentration, and mercury loading values, respectively, for this

trunkline and some of its tributaries. As noted for other subsystems,

the discharge values (Figure 3.3.16) reflect some inconsistencies that

may be related to measurement error, temporal variability, or actual

DISCHARGE (L/s)
NOVEMBER 17, 1983

<0.1

< 0.1 < 0.1

9204-4

10

5

9201-5

< 0.1 **37**

24 < 0.1

35

7

38

39
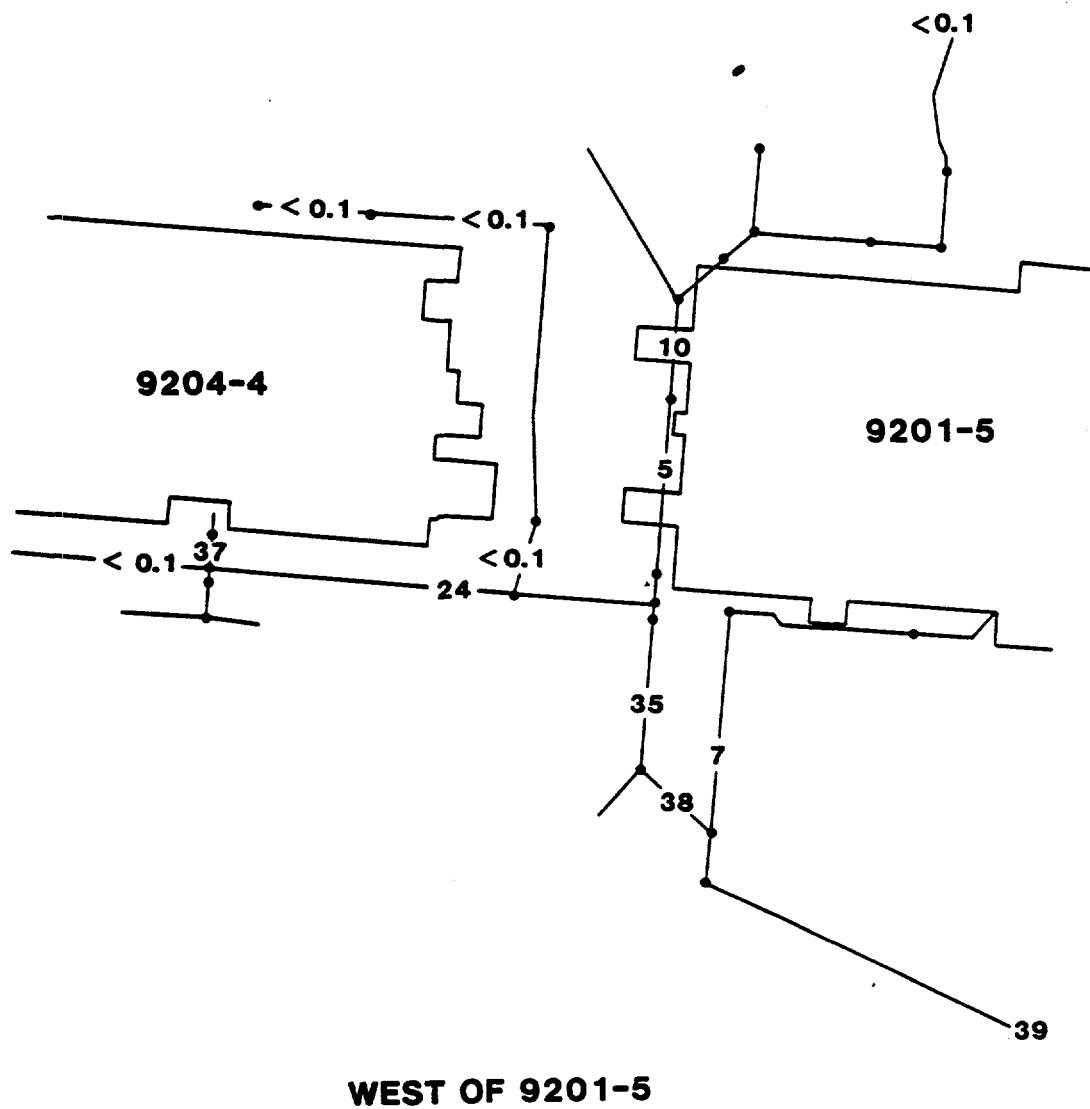
WEST OF 9201-5

Fig. 3.3.13. Instantaneous discharge values for sampling points located west of 9201–5.

**Hg CONCENTRATION (µg/L)
NOVEMBER 17, 1983**

24

<—<0.5—← 2

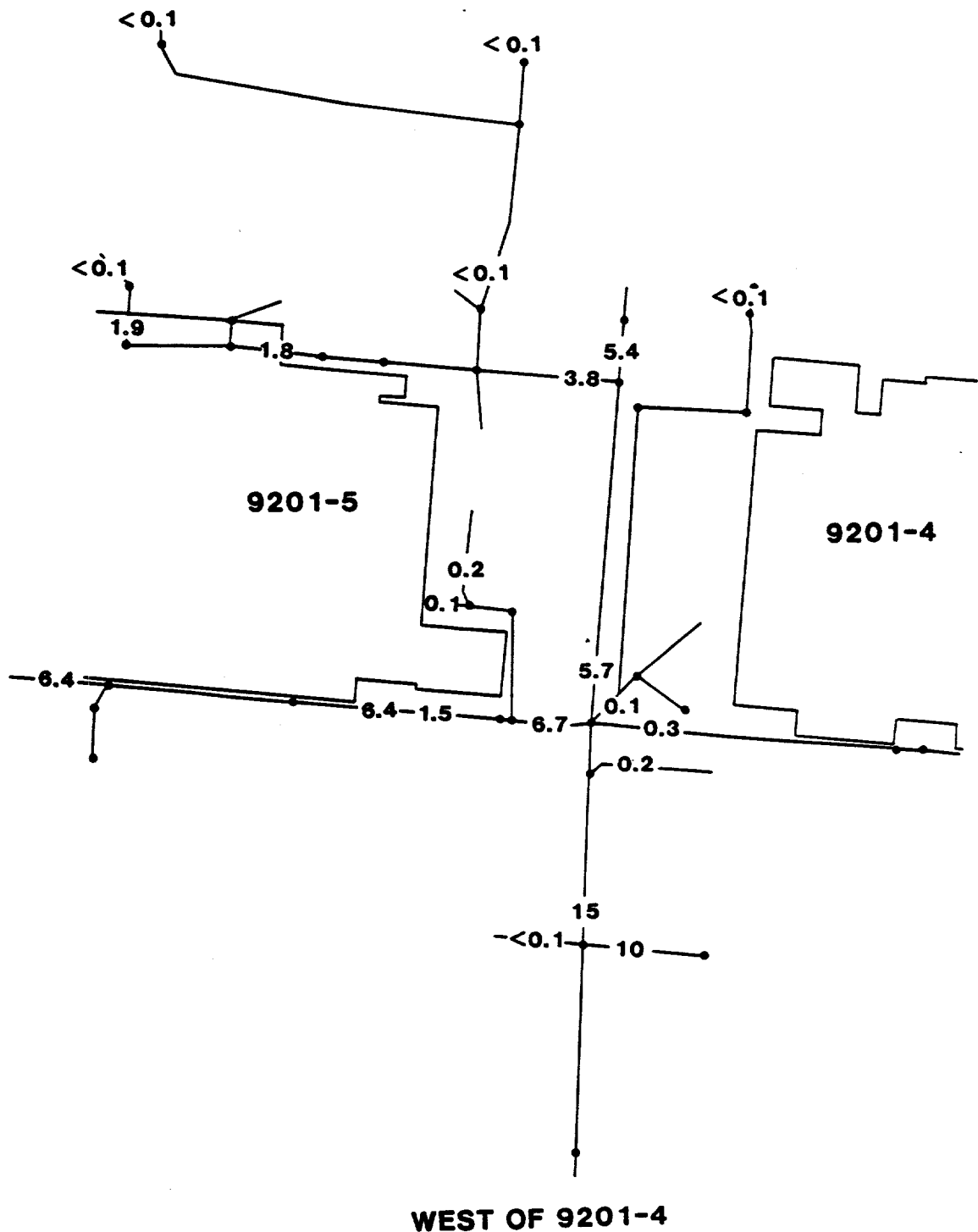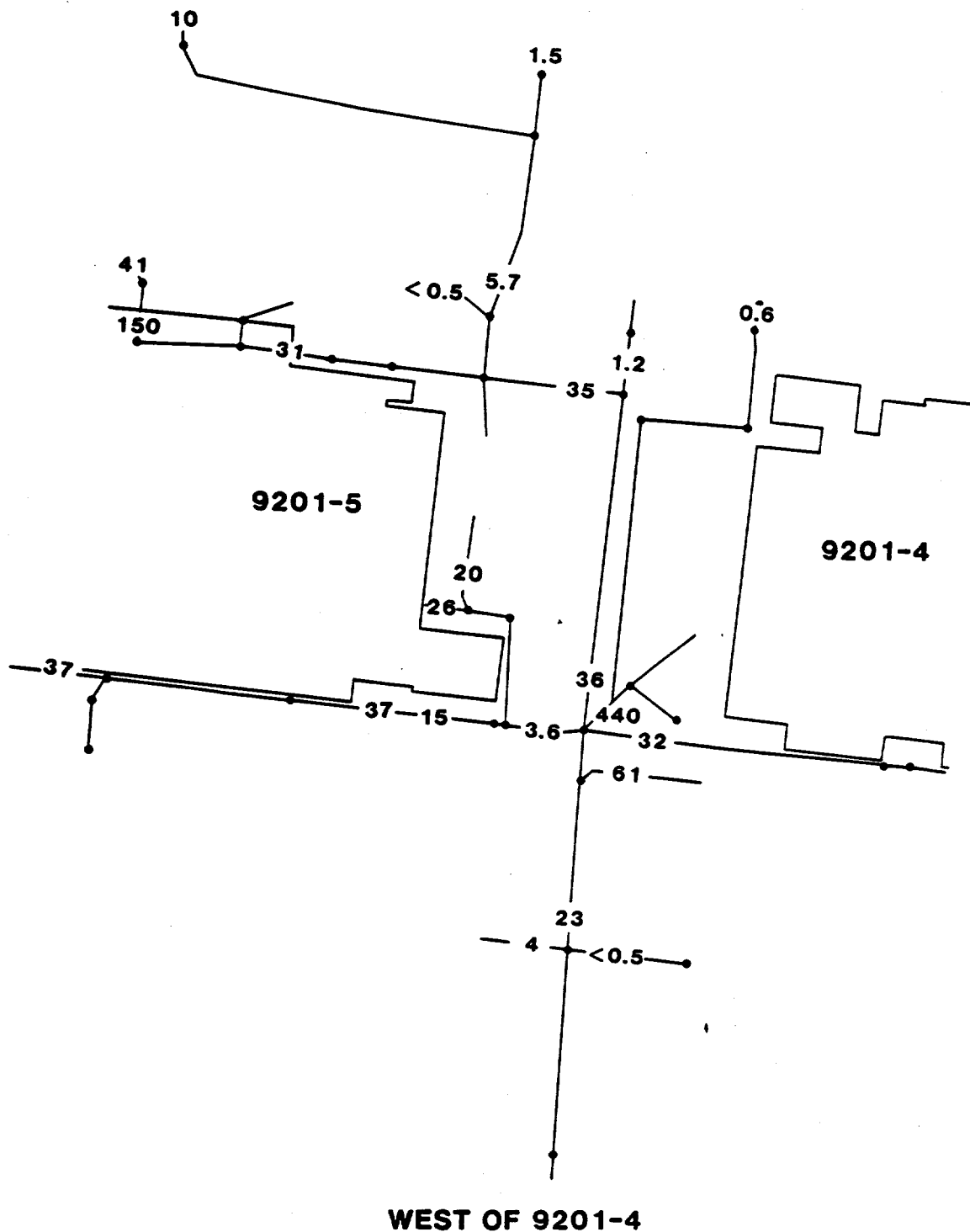**9204-4**

9201-5

1.0

1.0

500—19

0.5

2

29

5

7

9

8
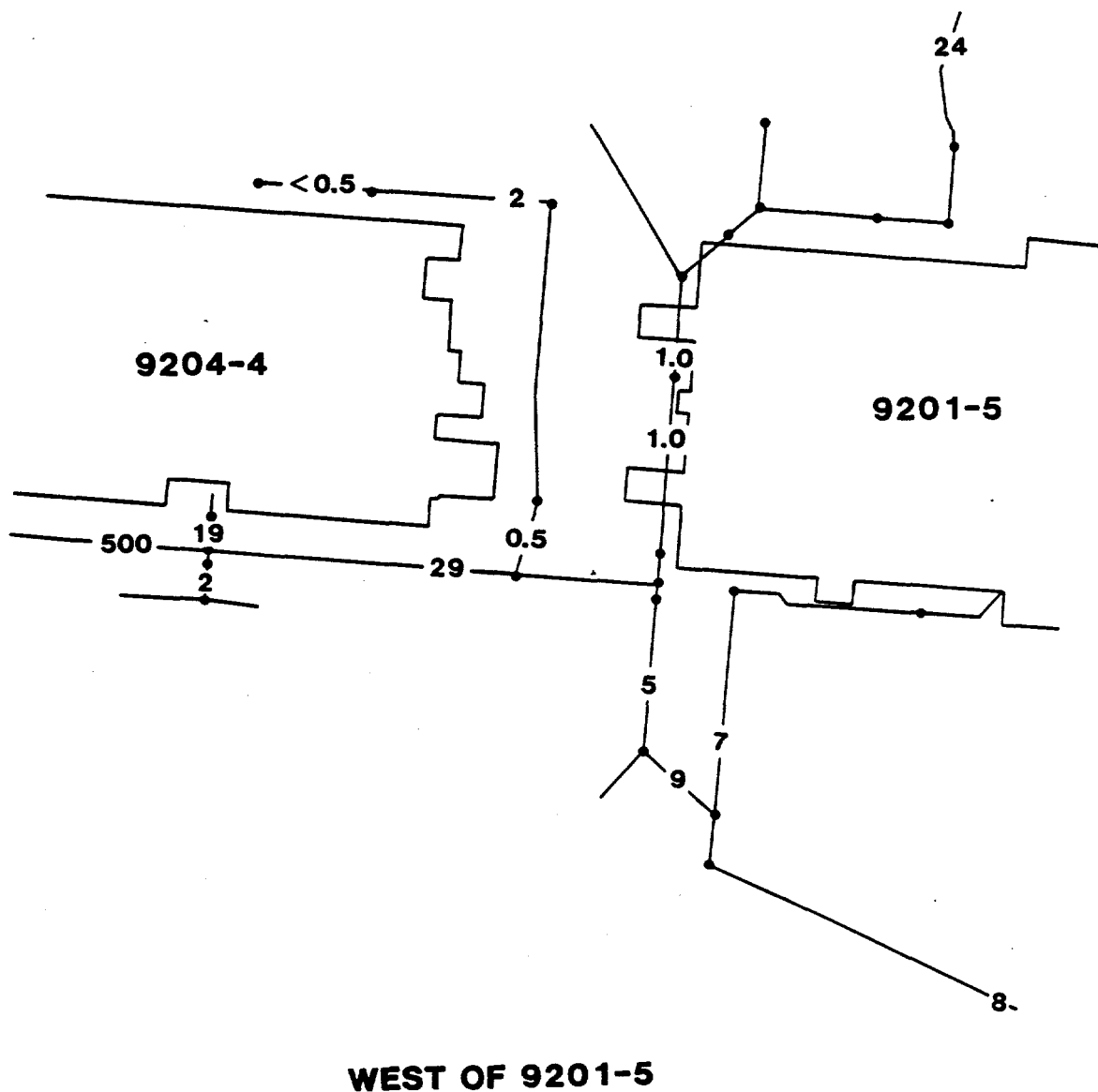
WEST OF 9201-5

Fig. 3.3.14. Mercury concentrations for sampling points located west
of 9201-5.

Hg LOADING (g/d)
NOVEMBER 17, 1983

< 0.1

9204-4

9201-5

0.9

0.4

0 — 0

0.5 64

1.9

60 0

< 1

15

4.4

30

27
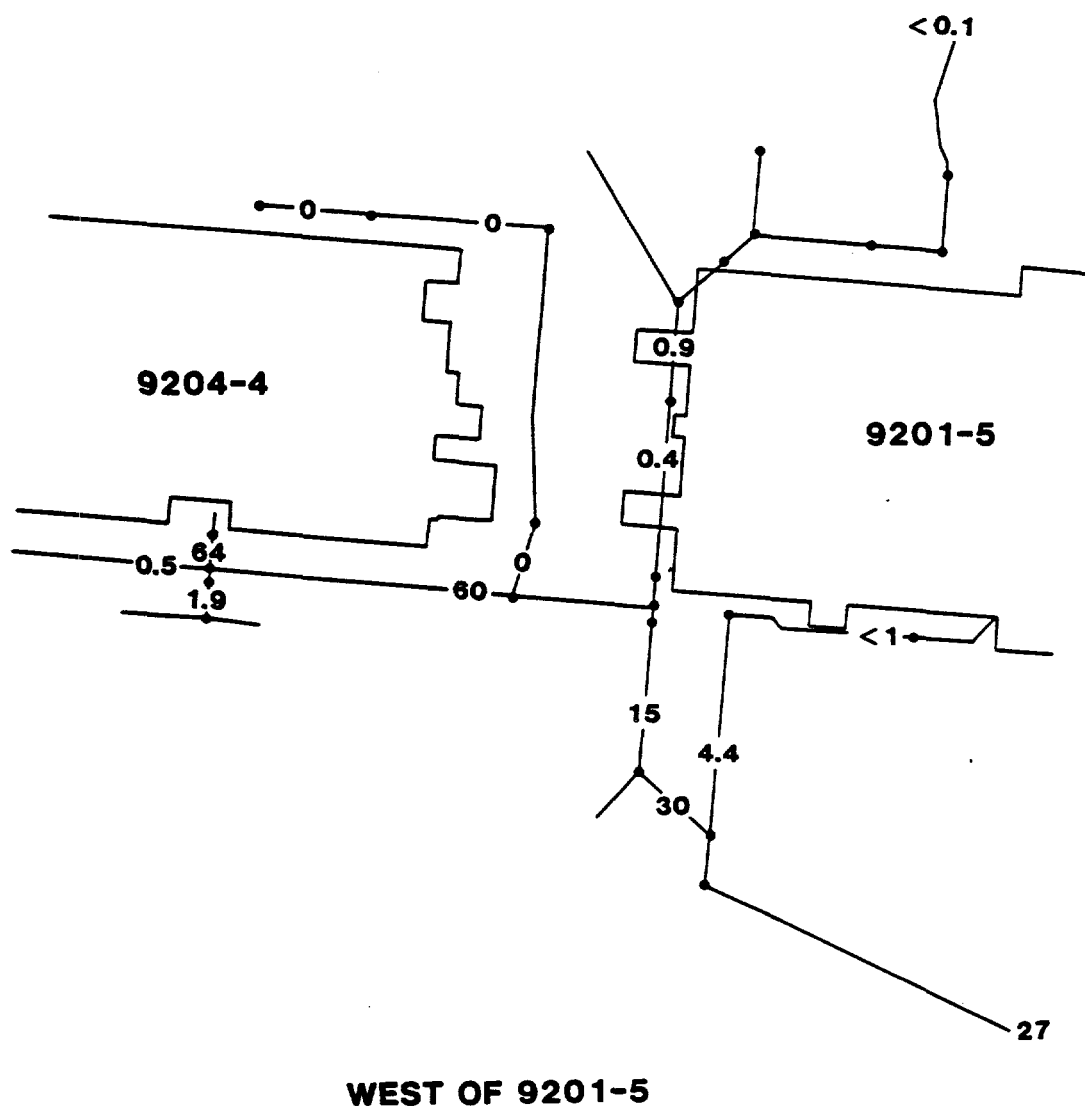
WEST OF 9201-5

Fig. 3.3.15. Mercury loadings for sampling points located west of 9201-5.

DISCHARGE (L/s)
DECEMBER 21, 1983

9204-4

2.8

0.2

0.5

0.9

0.1

2

6

12

6.3
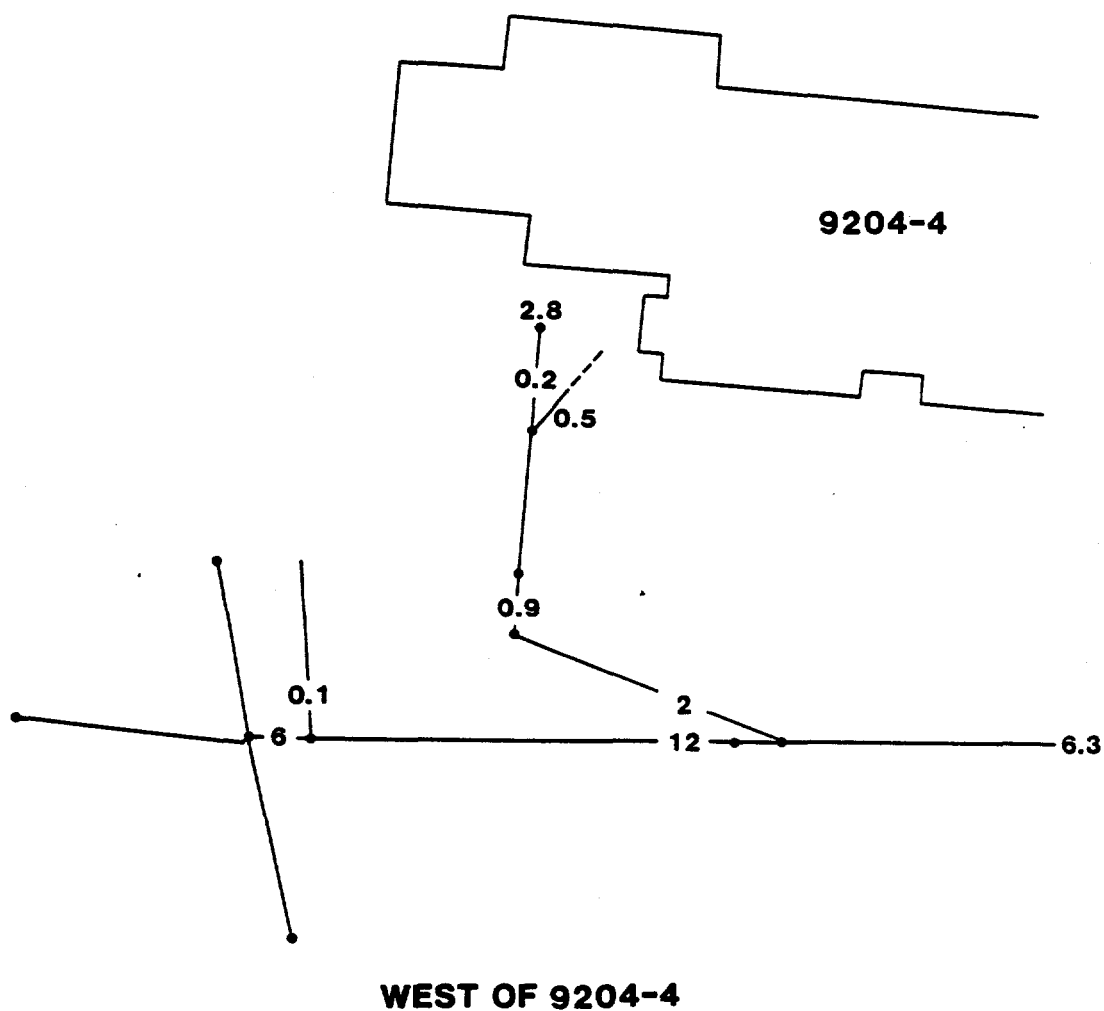
WEST OF 9204-4

Fig. 3.3.16. Instantaneous discharge values for sampling points
located west of 9204-4.

loss of water between measuring points. These inconsistences are not of much importance in this subsystem because mercury concentrations (Figure 3.3.17) and loadings (Figure 3.3.18) are relatively low. The data do indicate presence of some weak mercury sources in this subsystem and some metallic mercury was observed in pipes southwest of Building 9204-4.

Table 3.3.6 summarizes best estimates of mercury loading from the various buildings/areas in the Y-12 Plant Western Exclusion Area. The estimates are based on the detailed comprehensive surveys just presented plus data from the earlier surveys. It must be emphasized that these are estimates for non-stormflow conditions and "normal" plant operations. Summing the loadings for the Western Exclusion Area yield 130 g/d. Combining this subtotal with an estimate of 10 g/d for Building 9201-2 and 30 g/d for the 81-10 area yields a total plant loading to the industrial ditch of 170 g/d. The latter value is very similar to the estimated typical inflow mercury loading to NHP (i.e. ≈150 g/d).

81-10 Area

The contribution for the 81-10 area could not be measured directly due to lack of access to a sampling point in the South Pipe. The estimated contribution (about 30 g/d) was derived by subtracting measured upstream inputs into this pipe from the measured downstream point where this pipe discharges into the ditch (1719S). Since the material balance on inputs entering the North Pipe were close to the measured output of the North Pipe is was decided that this difference would be a reasonable approximation. Observations of the situation observed at 81-10 were as follows:

Hg CONCENTRATION (µg/L)
DECEMBER 21, 1983

9204-4

< 0.5

< 0.7

2.8

4.2

< 0.5

1.3

5

1.5

1.5

WEST OF 9204-4

Fig. 3.3.17.   Mercury concentrations for sampling pointed located west of 9204–4.
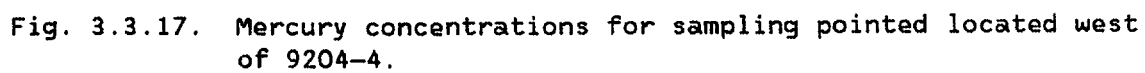
Hg LOADING (g/d)
DECEMBER 21, 1983

9204-4

< 0.1

< 0.1

0.1

0.3

0.8

0

0.7

1.5

0.8
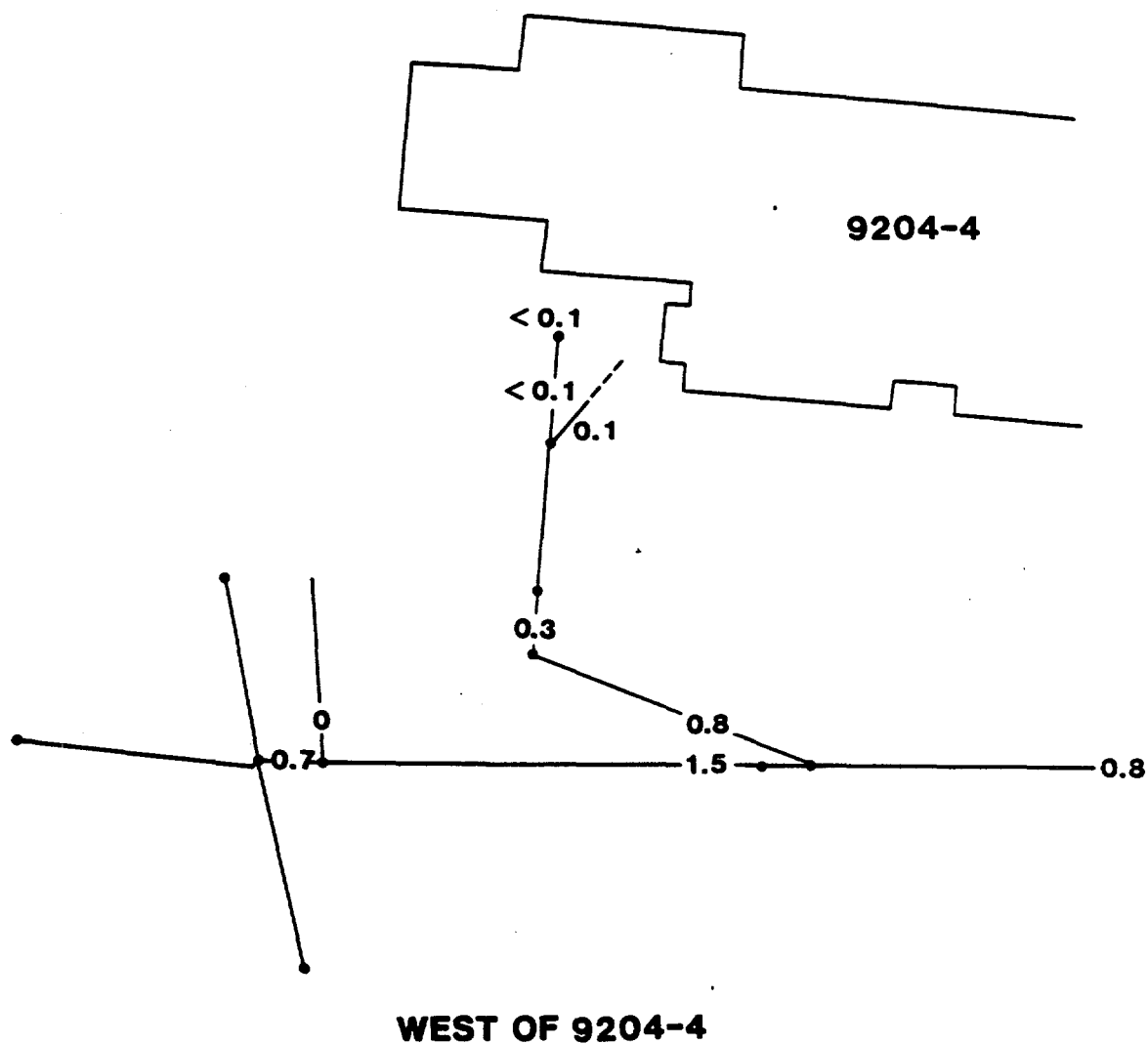
WEST OF 9204-4

Fig. 3.3.18. Mercury loadings for sampling points located west of
9204-4.

- Mercury contaminated sludges were stored in drums that were deteriorated. Rain could wash this material directly into a manhole leading to the South Pipe. This sediment material could sit in the bottom of the pipe and be released over time.

- The old Nichols-Hershoff furnace contained residual mercury that was leaking onto the concrete pad. The drain system on this pad was connected to a sump which overflowed into the South Pipe. Rain could wash this mercury into the sump. Sediments in the sump were heavily contaminated with mercury.

Other Surveys

During July through August 1983, Y-12 Plant effluents were sampled at selected locations by the ORNL Department of Environmental Management and the Engineering Division. Complete results of these surveys are given in Y-12 Report YSE-44. Neither of these surveys involved measurement of discharge at the sampling points and thus loading values cannot be calculated. The mercury concentration values can be compared with the values measured by us for equivalent

Table 3.3.6. Summary of best estimates of mercury loading
from various buildings/areas in the Y-12 Plant Western
Exclusion Area

Discharge Point	Main Buildings/Areas Served	Estimated Hg Loading (g/d)	Building Totals
E9811	Other areas	5	
	9201-4	10	
SW9727-4	9201-4	10	25(9201-4)
SW9401-3	9201-4	5	
	9201-5	25	
NE9720-5/N	9201-5	10	40(9201-5)
NE9720-5/NW	9201-5	5	
	9204-4	50	
NW9720-5/N	9204-4	5	55(9204-4)
	Other areas	5	
1719S	81-10	30	30(81-10)
	Other areas		

locations. Tables 3.3.7 and 3.3.8 summarize the mercury concentration data for these surveys conducted by others. In general the concentration values for locations in common with our surveys are comparable to our concentration values. Location E6(1312) in Table 3.3.8 stands out as being very high compared with our single value for this location. The maximum value of 310 µg/L, which causes the average to be so high, apparently resulted from a storm sample. This discharge point includes drainage from the 9733 complex of buildings where mercury was spilled (see Rothschild et. al. 1984) and thus should be traced upstream with sampling as was done in the Western Exclusion Area.

3.4 Temporal Drain Surveys

Two intensive surveys of the temporal variability in mercury concentration and loading were conducted. The first survey in October 1982 involved nine locations which were sampled six times over a 24-hr weekday period. The second survey involved a single location which was sampled 24 times over a 48-hr weekday period.

Table 3.4.1 gives results of the intensive 24-hr survey of water flow, mercury concentration, and other parameters in selected pipes and in the influent and effluent of NHP. The purpose of this initial survey was to assess the variability in flow, mercury concentration, and loading at a few selected locations over a 24-hr weekday period. The results indicate that, except for two locations, temporal variability

Table 3.3.7. Summary of mercury results from ORNL Department
of Environmental Management effluent sampling of ORNL
facilities at Y-12 Plant in July-August 1983.

Discharge Point	Average Hg (μg/L)	Minimum Hg (μg/L)	Maximum Hg (μg/L)	Number of Observations
22 (669)[1]	1.8	1	7	10
34 (763)	1.0	1	1	7
42 (851)	1.0	1	1	7
49 (915)	30.0	25	39	7
51 (935.6)	6.6	5	11	7
55 (980.5)	1.9	1	2	7
113 (1473.5)	1.0	1	1	6
122	1.1	1	2	6
125	1.6	1	5	7
133	2.0	1	3	2
142	1.1	1	2	7
147 (SW9204-3)	2.5	1	8	10
731	1.6	1	3	5

[1]Number in ( ) is equivalent station code for this study.

Table 3.3.8 Summary of mercury results from Y-12 Engineering
effluent sampling of selected discharge points.

Discharge Point	Average Hg (µg/L)	Minimum Hg (µg/L)	Maximum Hg (µg/L)	Number of Observations
E1 (NW9720-5/W)[1]	2	<1	3	5
E2 (SE9720-5/N)	10	6	21	5
E3 (1719N)	17	9	28	5
E4 (1719S)	7	6	10	5
E5 (1710.8)	1	<1	<1	5
E6 (1312)	65	<1	310	5
E7 (SE9202)	1	<1	<1	5
E8 (667)	1	<1	3	5
E9 (NHP-inflow)	4	4	6	5
E10	1	<1	2	5
E11	2	1	4	5
E13	5	2	14	5
E14	1	<1	<2	5
E15	1	<1	<1	5
E16 (SW9401-3/N)	30	9	41	5
E17	4	<1	17	5
E23	3	2	6	5
E24 (SW9727-3/N)	8	6	10	5

[1]Number in (   ) is equivalent station code for this study.

Table 3.4.1. Results of intensive (24-h) survey of water flow, mercury concentration, and other
parameters in selected pipes and in the influent and effluent of New Hope Pond

Station	Date	Time	Flow (L/s)	pH	E.C.^{a} (μS/cm)	T°C	Cl^2 (mg/L)	Cl$^-$ (mg/L)	ΣHg (mg/L)	Hg Loading (g/d)
NHP outflow	10/28/82	0820	372	6.8	355	16	0.00	16	1.8	58
	10/28/82	1344	364	7.5	311	21	0.00	14	2.5	80
	10/28/82	1758	379	7.8	341	22	0.00	14	2.7	88
	10/28/82	2055	372	7.4	365	21	0.00	21	2.1	68
	10/28/82	2400	364	7.1	366	20	0.00	23	1.7	53
	10/29/82	0335	357	7.3	332	19	0.00	17	2.0	62
	10/29/82	0600	357	7.3	320	18	0.00	14	1.9	57
NHP inflow	10/28/82	0855	372	6.8	299	19	0.05	9	4.4	141
	10/28/82	1400	364	8.4	337	24	0.04	15	3.1	96
	10/28/82	1805	379	6.9	361	23	0.02	24	3.9	128
	10/28/82	2105	372	7.0	295	21	0.01	20	3.7	119
	10/29/82	0010	364	7.2	285	21	0.06	9	4.3	135
	10/29/82	0340	357	7.4	285	20	0.08	9	4.4	136
	10/29/82	0610	356	7.6	288	21	0.09	8	4.5	140
667	10/28/82	0920	18.9	7.2	246	22	1.10	9	0.52	0.85
	10/28/82	1415	20.3	7.6	289	28	3.70	15	0.91	1.6
	10/28/82	1822	17.6	7.5	262	24	0.95	9	0.24	0.36
	10/28/82	2122	18.2	7.6	247	24	0.32	7	0.18	0.28
	10/29/82	0025	17.6	7.6	252	23	0.25	7	0.15	0.23
	10/29/82	0400	17.6	7.6	234	22	0.48	7	0.16	0.24
910.4	10/28/82	0940	21.3	6.9	240	20	1.20	6	0.13	0.24
	10/28/82	1425	21.3	7.1	250	23	1.15	7	0.10	0.18
	10/28/82	1825	20.0	7.1	187	33	1.35	7	0.08	0.14
	10/28/82	2134	21.9	7.2	234	21	1.20	6	0.09	0.17
	10/29/82	0040	23.2	7.2	235	21	1.18	7	0.05	0.10
	10/29/82	0420	26.6	7.0	235	20	1.25	7	0.07	0.16
915	10/28/82	0955	4.2	7.3	261	18	0.35	7	13	4.7
	10/28/82	1435	2.3	7.5	218	22	1.00	6	41	8.2
	10/28/82	1845	2.1	7.3	253	21	3.40	8	22	4.0
	10/28/82	2140	2.6	7.5	206	20	0.92	6	32	7.2
	10/29/82	0045	2.6	7.6	214	20	0.85	6	37	8.3
	10/29/82	0430	2.6	7.4	202	19	1.00	6	32	7.2
1710.8	10/28/82	1015	32.4	7.3	264	27	0.70	7	0.18	0.50
	10/28/82	1458	27.8	7.6	264	29	0.80	7	0.21	0.50
	10/28/82	1855	29.0	7.5	247	28	0.75	8	0.15	0.38
	10/28/82	2200	31.2	7.8	287	27	0.58	9	0.18	0.49
	10/29/82	0108	26.8	7.6	248	28	0.77	7	0.16	0.37
	10/29/82	0445	29.0	7.5	240	28	0.83	7	0.17	0.43

Table 3.4.1 (Continued)

Station	Date	Time	Flow (L/s)	pH	E.C.[a] (µS/cm)	T°C	Cl^2 (mg/L)	Cl$^-$ (mg/L)	ΣHg (mg/L)	Hg Loading (g/d)
E9811/N	10/28/82	1040	54.6	7.1	263	25	0.00	8	2.8	13.2
	10/28/82	1600	54.6	7.2	252	26	0.06	8	2.9	13.7
	10/28/82	1910	54.6	10.7	1,509	26	0.68	14	4.1	19.3
	10/28/82	2223	55.4	7.2	247	25	0.48	8	1.9	9.1
	10/29/82	0135	55.4	9.4	447	24	0.48	9	2.4	11.5
	10/29/82	0510	53.8	7.6	252	25	0.48	9	3.1	14.4
S29727-4/N	10/28/82	1300	3.9	7.4	882	27	0.02	150	61	20.6
	10/28/82	1530	29.9	2.4	4,223	21	0.00	300	2.1	5.3
	10/28/82	1925	2.2	6.7	535	28	0.07	56	14	2.7
	10/28/82	2235	3.0	7.4	526	27	0.06	43	7.3	1.9
	10/29/82	0152	2.8	7.5	512	25	0.06	37	8.7	2.1
	10/29/82	0522	3.2	7.6	393	25	0.07	22	9.5	2.6
NW9720-5/W	10/28/82	1315	9.6	7.0	758	21	0.00	5	1.2	1.0
	10/28/82	1630	9.6	6.8	772	21	0.00	8	1.1	0.91
	10/28/82	1945	9.6	6.8	772	20	0.00	8	1.3	1.1
	10/28/82	2247	16.8	6.9	755	21	0.00	8	1.4	2.0
	10/29/82	0210	13.2	6.9	778	20	0.00	8	1.3	1.5
	10/29/82	0540	11.2	6.9	774	20	0.00	8	1.2	1.2

[a]Electrical conductance

was relatively low (Table 3.4.2, C. V. $\leq$ $\pm$40). Station 667 (Pipe No. 27) exhibited low variability in flow ($\pm$5.9%) but relatively high variability in mercury concentration. This pipe received periodic discharge from the plant laundry[1] and thus the highest Hg concentrations (0.52 and 0.91 µg/L) occurred during the day shift when the laundry was in operation. The other location with high variability was SW9727-4 (Line No. 160) which exhibited variability in both flow ($\pm$ 146%) and Hg concentration ($\pm$128%). This pipe received both sump drainage from 9201-4 and one daily pulse loading of acidic backwash from the condensor water treatment system for the Y-12 Steam Plant. The low pH (2.4), high electrical conductance (4223 µS/cm) and high flow (29.9 L/s) for the sample taken at 1530 hr. indicates that resin backwashing was occurring. There are also at least 8 sumps in the basement of 9201-4 with water level activated pumps which operate periodically. These sumps contained some metallic mercury and sludges. Cleanup operations in March-June 1983 recovered approximately 9,000 lbs (4100 kg) Hg from sumps in 9201-4 and 9201-5. Metallic Hg is soluble to the extent of about 25-70 µg/L and thus the value of 61 µg/L for the sample obtained at 1300 hr. on October 28, 1982 is highly suggestive of water that has been in contact with metallic Hg long enough to approach saturation, i.e., sump water standing over a pool of mercury. The frequency of sump pump operation is unknown, but one inspection of two sumps suggested that the pumps might be activated several times daily for perhaps 2 to 5 minutes. The source of the small flow of water into 9201-4 sumps was not investigated but is believed to be groundwater.

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[1]Operation of the plant laundry was subsequently discontinued.

Table 3.4.2. Coefficients of variation (%) for flow rate, mercury
concentration, and mercury loading over a 24-h period
(October 28-29, 1982). Based on grab samples
collected approximately every 4 h

Station	Flow (%)	Total Hg (%)	Hg loading (%)
NHP outflow	2.2[a]	18	19
NHP outflow	2.2[a]	13	12
667	5.9	84	91
910.4	10	32	28
915	27	35	27
1710.8	7.1	12	14
E9811/N	1.1	26	25
SW9727-4	146	128	125
NW9720-5/W	24	8.4	33

[a]Assumed inflow rate equal to measured outflow rate.

Overall the results of the initial intensive survey indicated that variability in flow and Hg concentration can be quite high in some pipes due to episodic plant operation. However, in every case only a single grab sample would have accurately identified all pipes with significant (≥ 1 µg/L) concentration of Hg. Thus it was concluded that collection of only a single grab sample at all pipes would provide at least an initial screening for significant sources.

The second intensive survey of temporal variability involved pipe S9204-4/N and was prompted by apparent high variability in Hg concentration and loading at this location, and at measuring points downstream, noted during the extensive surveys. On November 17, 1983 at 1030 hr. the Hg concentration and loading were 19 µg/L and 63 g/d, respectively. At this loading rate, pipe S9204-4N represented about 50% of the total mercury loading for the upper creek. On August 8-9, 1984 concentrations were 3.9 and 8.0 µg/L at 1310 (8/8/84) and 1005 (8/9/84), respectively, while loadings were 7.9 and 17 g/d, respectively. From these limited data it was impossible to determine whether the variability was short-term and cyclical over a 24-hr period or long-term and related to some permanent change in the mercury source.

On October 3, 1984 a Manning Model S4040 discrete wastewater sampler was installed temporarily on pipe S9204-4/N. The sampler was loaded with 24 500-mL bottles containing 10 mL of concentrated HNO_3 as a mercury preservative (in accordance with EPA protocol) and set to collect samples every 2 hours beginning at 1415 on October 3, 1984. Water flow rate was not monitored over the 48-hr. sampling period. Thus only mercury concentration data was obtained.

As shown in Fig. 3.4.1, mercury concentration over the 48-hr period varied over a wide range (2.5 to 16.5 µg/L). Generally the highest concentrations occurred during the third shift (midnight to 0800) and the lowest concentrations occurred during the afternoon. This pattern suggests that higher flows of cooling water during daylight hours are diluting a relatively constant source (possibly a spring). Confirmatory studies for this hypothesis had not been conducted prior to the time this report was prepared.

3.5 On-line Monitoring

An automatic on-line mercury monitoring system was installed on New Hope pond in January 1985. The system was designed by E. R. Hinton and others of the Y-12 Plant Laboratory and has measured mercury concentrations in the influent and effluent of NHP on an hourly basis. Mercury vapor is generated by the acidification of a 25 mL sample with an $HNO_3-H_2SO_4$ mixture, followed by the addition of a $KMnO_4$ solution and reduction with $NaBH_4$. Preliminary data from the system using the procedure have shown good agreement with the recommended EPA procedure using a 2-hr. digestion. On-line data for the period January 9 – February 3, 1985, were available for inclusion in this report. This period was characterized by extremely cold weather (average was 9°F below normal), several snow and ice storms with abundant use of deicing salt at Y-12, and one heavy rainfall (2.6 inches). Although the weather during this period was representative of a
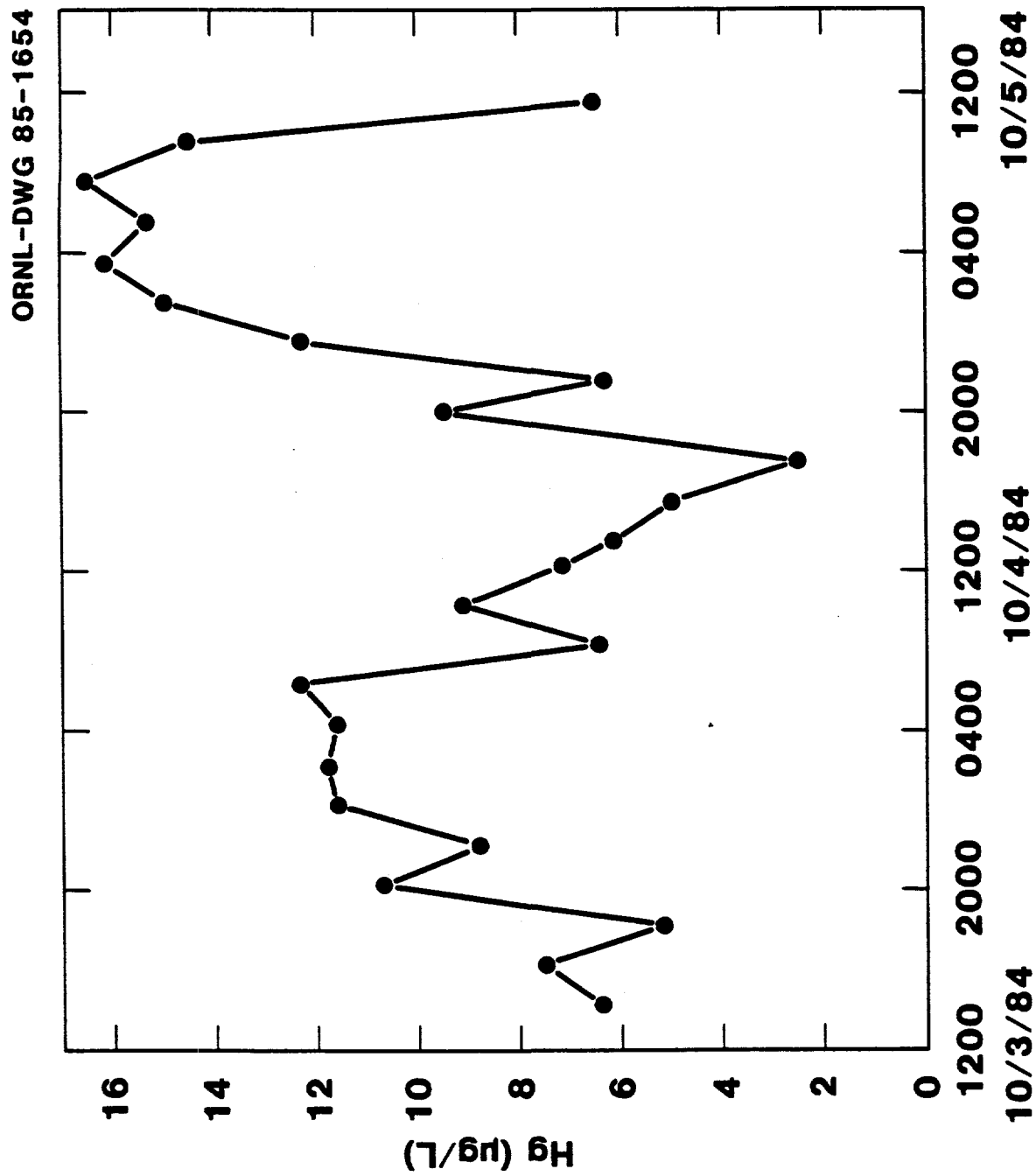
Fig. 3.4.1. Variation in mercury concentration at S9204—4/N over a
48-h period, October 3–5, 1984.

typical January, the monitoring data should not be viewed as necessarily representative of other periods during the year. Nonetheless, the available on-line monitoring data provide the first opportunity to examine short-term variability in mercury concentrations at NHP and particularly provide the best data available for a large storm event.

Average NHP influent mercury concentrations were ~2 µg/L. Graphs of mercury concentrations versus time (Figure 3.5.1) show several relatively high peaks (up to 17 µg/L) in concentration. As discussed subsequently some of these correspond with precipitation (rain or snow) events and associated high discharge. Inspection of the daily records revealed a relatively common pattern of near-midday peaks in influent Hg concentration. Patterns for three Wednesday (1/16, 1/23, 1/30) in a row revealed two peaks in influent concentration, one between 1000 and 1200 hours and one between 1600 and 2000 hours. Figure 3.5.2 shows one example of this diurnal pattern in Hg concentration.

No cause for these peaks in the on-line data has yet been identified but several hypotheses are suggested:

1. Periodic process discharges, such as acidic backwash from the steam plant, temporarily increases the dissolution of mercury trapped in pipes and creates a pulse load of higher mercury drainage waters.

2. Periodic pumping of basement sumps containing elevated mercury waters creates a pulse load of mercury to NHP.

NHP EFFLUENT

NHP INFLUENT

SAMPLE NUMBER
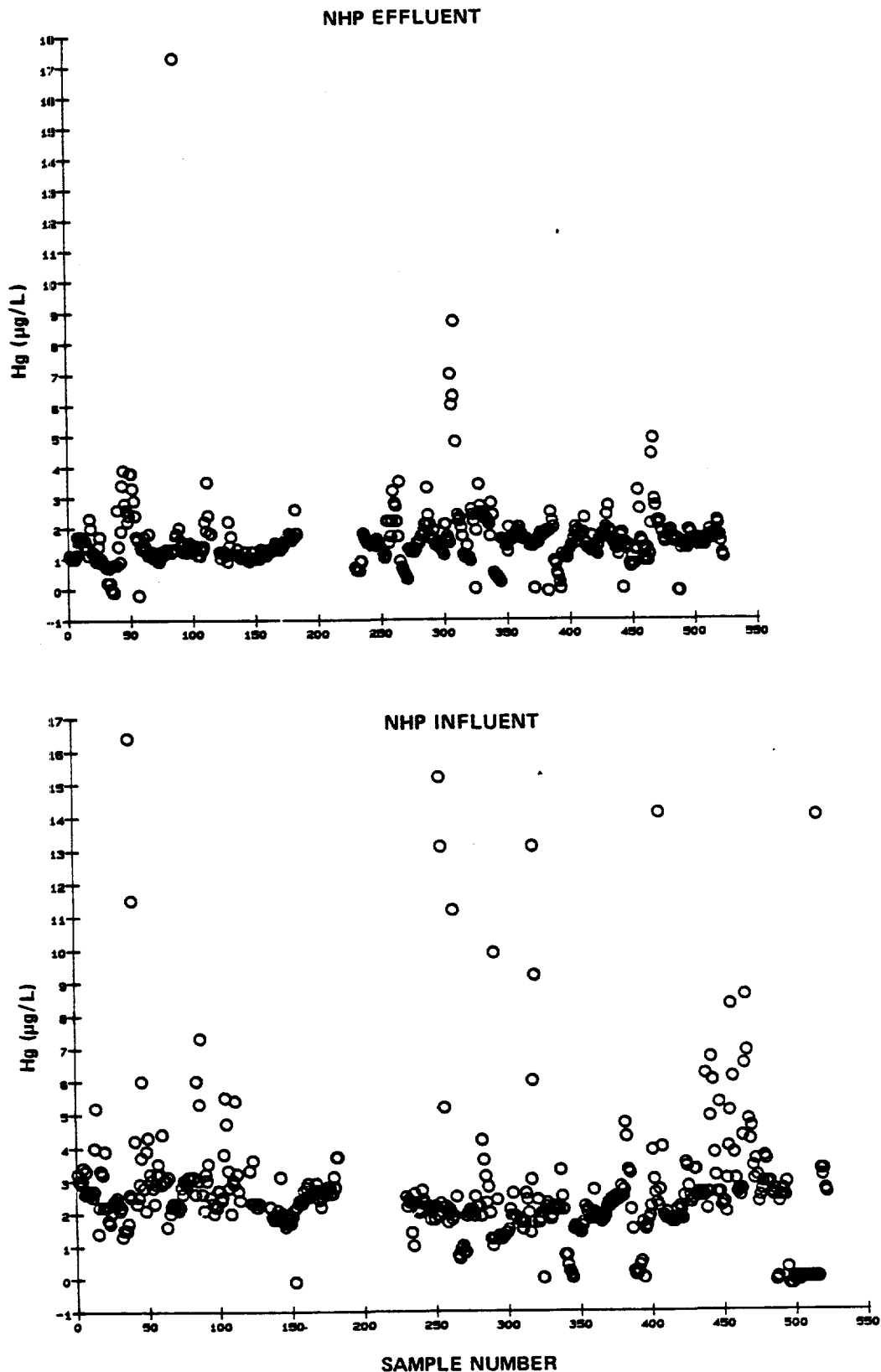
Fig. 3.5.1.   Results of on—line monitoring of mercury concentrations in
the influent (top plate) and effluent (bottom plate) of
NHP for the period January 9, 1985 through February 3,
1985.
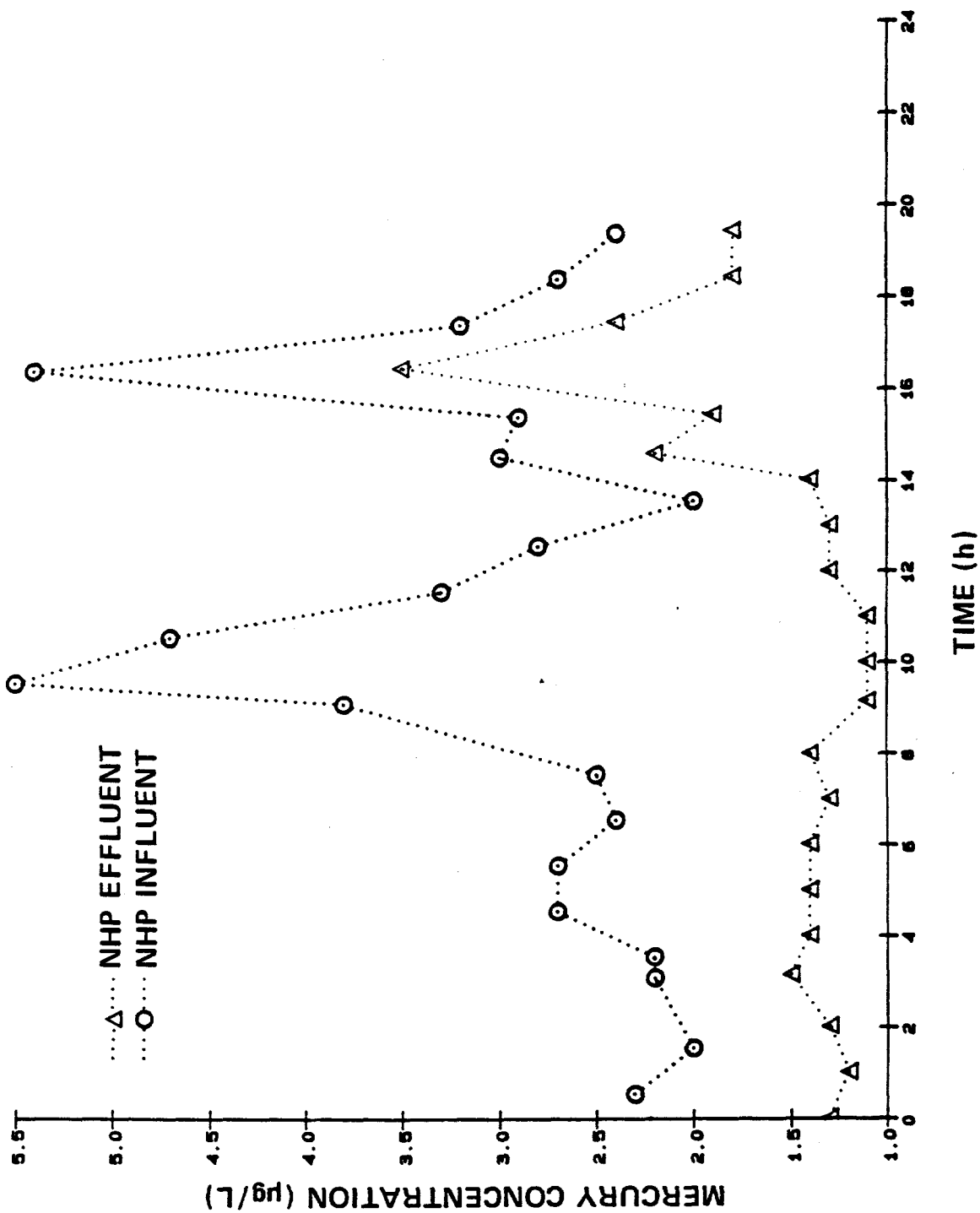
Fig. 3.5.2.   Variation in mercury concentrations (on—line monitor data) at influent and effluent of NHP on January 30, 1985.

3. Mercury concentrations in drainage waters in the open ditch and
    upstream pipes increase at night when many plant operations, which
    provide dilution water, are shut down. Morning start-up flushes this
    higher mercury water into NHP.

None of these hypotheses can explain all of the data. Additional
on-line monitoring data and dye tracing studies will be necessary to
identify the cause of the daily peaks which are not associated with
stormflow.

The on-line monitor provided excellent data for a large storm event
that occurred between January 31 to February 2, 1985. Total rainfall for
this storm was 2.6 inches, with a maximum intensity of 0.25 inches/hour.
Hourly rainfall and the storm hydrograph for NHP are show in Figure 3.5.3.
Peak discharge for this storm was 2.04 m^3s (46.5 mgd) and thus
represented about a 7-fold increase over typical baseflow discharge. As
expected, the storm hydrograph was a virtual mirror image of the storm
hyetograph, with each peak in rainfall intensity corresponding with a peak
in discharge. The high percentage of impervious surface area in the plant
area accounts for this correspondence.

The on-line monitor data for the storm are displayed in Figure 3.5.4.
The peak mercury concentration in the influent (8.6 µg/L) occurred at the
peak discharge for the storm. The peak mercury in the effluent (4.9 µg/L)
occurred one hour after the peak discharge. With few exceptions the
secondary peaks in mercury concentration in both the influent and effluent
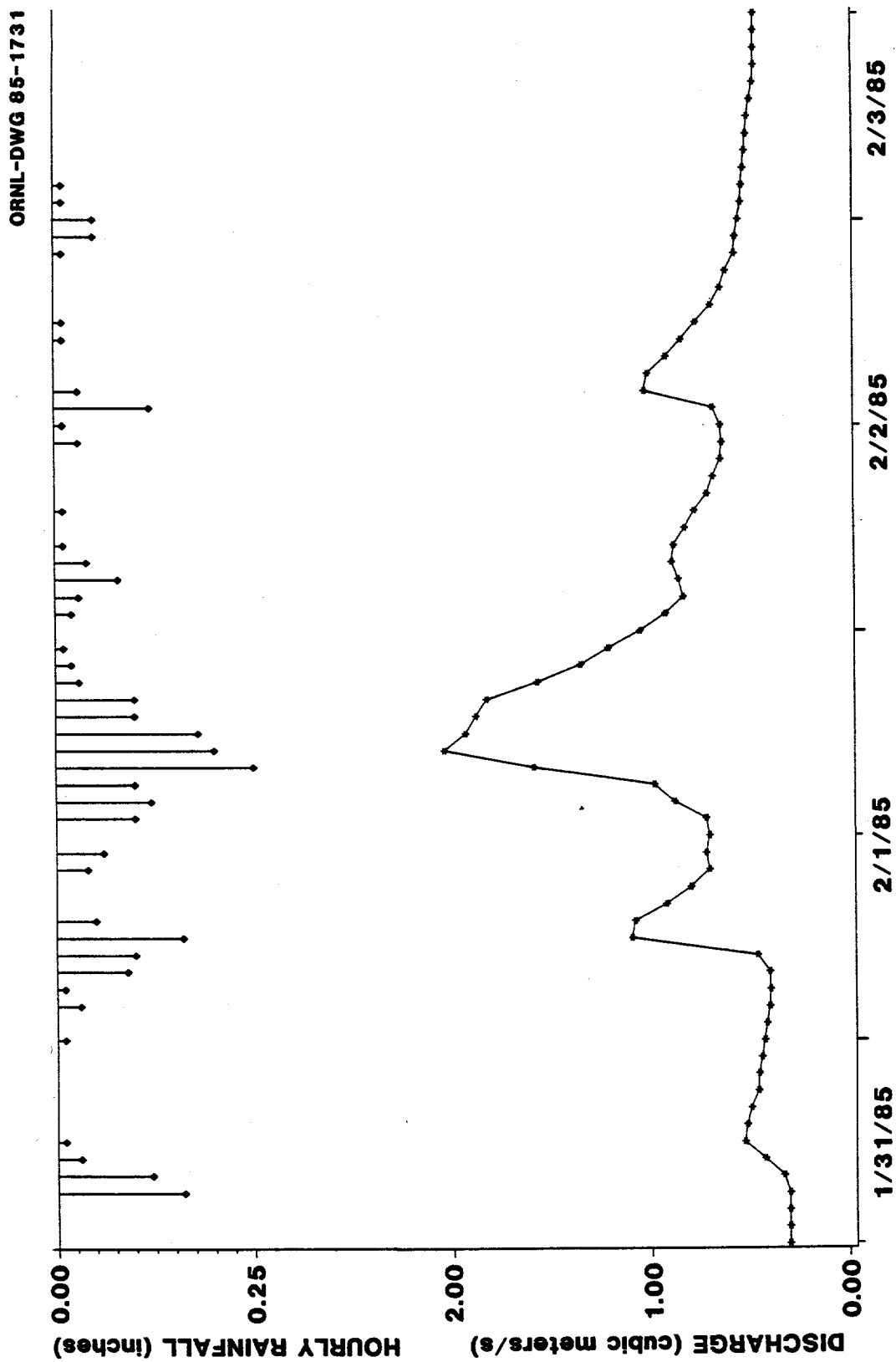
Fig. 3.5.3. Hourly rainfall and discharge for NHP between January 31, 1985 and February 3, 1985.

ORNL-DWG 85-1731

ORNL-DWG 85-10993
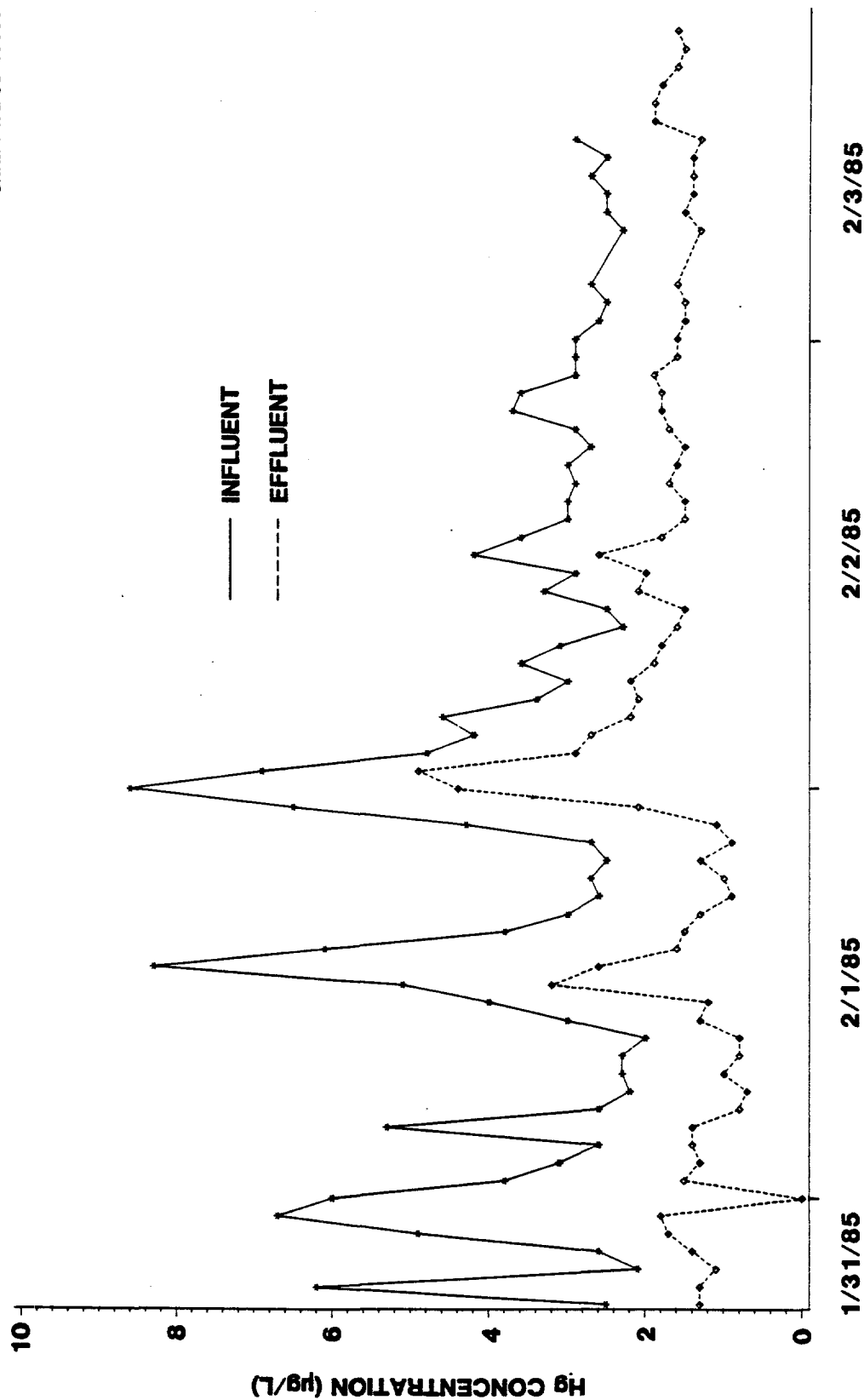
Fig. 3.5.4 Variation in mercury concentrations (on-line monitor data) in the influent and effluent of NHP between January 31, 1985 and February 3, 1985.

corresponded with the secondary peaks in discharge. In spite of the high flow and obvious short hydraulic residence time of storm water in NHP, effluent mercury concentrations were consistently lower than influent concentrations. Effluent Hg concentrations were increased by about a factor of 4 for this storm but this represents the maximum difference observed (at peak discharge). In comparison with non-stormflow periods, even this maximum factor of change in Hg concentration is surprisingly small. Diurnal changes in concentration on non-storm days often exceed a factor of 4. Because mercury loading rate is the product of mercury concentration and discharge, mercury loading rates were greatly increased by the storm. At peak discharge the influent mercury loading was over 1500g/d while the effluent loading was about 800 g/d. These high loadings were sustained for only a short period (<2 hours) but represent the equivalent of a 24-hour period of mercury loading under baseflow conditions.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Small quantities of mercury continue to be mobilized and transported offsite from historic deposits in buildings and the drainage system at the Y-12 Plant. Since 1977, annual average mercury concentrations in plant discharge to East Fork Poplar Creek (NHP outflow) have ranged from 1.4 to 5.0 µg/L and annual average loadings have ranged from 11.3 kg (31g/d) to 76.6 kg (210 g/d). The upper limits of these ranges were recorded in the period 1982-83 when sampling frequency was first greatly increased. This does not necessarily imply an actual increase in mercury concentrations and loadings; previous concentrations and loadings may have been higher but not sampled during peak periods. Stormflow and plant upsets (eg., waterline break in Building 9201-4) have temporarily increased mercury concentrations and loadings in NHP influent and effluent.

NHP has acted as a very effective trap for mercury transported into it by plant drainage waters. During the period July 1983 through June 1984, 16 to 74 percent of the monthly influx of mercury to the pond was trapped. The overall average trap efficiency was 50%. Trap efficiency of NHP was inversely correlated with the monthly inflow of water.

Comprehensive surveys directed at localizing buildings and areas within the plant which contribute significant amounts of mercury to drainage waters revealed elevated mercury concentrations and loadings in the vicinity of nearly all buildings and areas where mercury was formerly used

or spilled. The largest loadings were associated with Buildings 9204-4 (55 g/d), 9201-5 (40 g/d) and 9201-4 (25 g/d). Building 9201-2 contributed an additional 10 g/d with all other areas combined yielding another 10 g/d. The estimated 81-10 area contribution was about 30 g/d.

Some individual sources of mercury were observed to be highly variable over short time periods (minutes to hours) apparently in response to cyclical plant operations (eg., regeneration of water treatment system at steam plant). Often both water flow and mercury concentration increased, resulting in periodic, greatly-increased mercury loading. Continuous on-line monitoring of mercury in the influent and effluent of NHP has also shown diurnal variations in mercury concentration which appear to be related to cyclical plant operations. On-line monitoring of one large storm event at NHP showed temporally-corresponding discharge and mercury concentration peaks, and a consistent pattern of inflow concentrations exceeding outflow concentrations. The on-line monitoring data also revealed that diurnal variations in mercury concentration on non-storm days were often greater than the changes associated with storm flow days.

This investigation has identified the most important source areas for mercury. Areas of secondary importance, such as the area near Buildings 9103 and the 9733 complex should ultimately be investigated further. The nature of the most important sources, such as the outfall on the south side of Bulding 9204-4, is still not fully understood. Residual deposits of metallic mercury were observed in most of the drain lines exhibiting significant mercury loading. Thus the general hypothesis that otherwise "clean" groundwater, cooling water, and process water solubilize or resuspend mercury while flowing through the drainage system appears to be supported.

4.2 Recommendations

Monitoring - The following recommendations are suggested in the area of monitoring:

1. Continue to support operation and improvement of on-line mercury monitor on the inflow and outflow of NHP.

    The data being generated by this instrument will be valuable in continuing to track sources of mercury and in quantifying the effectiveness of remedial actions to reduce mercury in plant effluents.

2. Continue to collect weekly, or more frequent, grab samples for mercury analysis at the inflow and outflow of NHP. Assure that discharge at time of sampling is recorded.

    The weekly grab sampling program has now been running for over 8 years. Future analysis of trends in mercury losses from the plant will benefit from continuing this program. The grab sampling program should if possible, be coordinated with the on-line monitoring to provide quality assurance checks on the on-line monitor.

3. Establish routine monitoring sites for mercury at near these locations: 915, E9811/N, SW9727-4/N, SW9401-3/N, NE9720-5/N, SW9404-20/N. Conduct grab sampling at weekly intervals. Install discharge gauging equipment, such as inductive collars for velocity and stage, so that an estimate of flow can be recorded at each sampling.

    These discharge points constitute the most significant sources of mercury to drainage water and should be closely monitored as various remedial actions are taken.

4. Unless required by the NPDES permit, discontinue analyzing the monthly NHP composite sample for mercury.

As this sample has been generated and handled in the past, analysis for mercury was inappropriate (due mainly to lack of preservation). The monthly composite values for mercury do not appear to represent typical values for most months. Furthermore the resulting data have been insensitive to short- and long-term trends in mercury concentration. If composite samples for mercury must be collected because of the NPDES permit, then install a dedicated sampling system with suitable sample perservative in the receiving bottle.

Recommendations: Remedial Actions

The storm sewer system leading into Upper East Fork Poplar Creek was constructed 40 years ago. The underground pipes have deteriorated to the point that either infiltration or exfiltration will occur, depending on the relationship between pipe elevation and the water table.

Considerable quantities of sediment, found to be mercury contaminated, were observed in the storm sewer system, along with small pools of metallic mercury where the structural integrity of the storm sewer system was intact. Where the pipe was not intact, small beads of mercury were frequently observed. This leads to the conclusion that, where mercury had gone down pipes with broken or separated bell joints,

some of the mercury had exfiltrated into the surrounding gravel and soil. Debris and manmade structures (security grates) clogged with debris created dams with quiescent zones behind them where sediment could and did accumulate. These sediments are readily accessible to resuspension when disturbed by any number of actions--natural actions such as storm events, plant operations such as turning on pumps that discharge into the storm sewer system, or removing clogged debris which changed the water flow and resuspended sediments.

Metallic mercury was observed in the sumps of buildings 9201-4 and 9201-5 which discharged into the storm sewer system. It was also observed in the basements of these buildings, apparently seeping out of the hollow tile block walls and other places in the building structure.

The 81-10 area contained the old Nichols-Hershoff Furnace, formerly used to recover mercury from sludges, which was leaking mercury in small quantities onto the pad. The area also was used to store drums of mercury sludges which had deteriorated to the point that mercury could escape from these drums and find its way into the storm sewer system.

From the initial comprehensive drain line survey and subsequent inspections, it was concluded that there was no single source of mercury entering East Fork Poplar Creek; and, in fact, there are many sources covering a wide area. The following recommendations were made in January 1983:

- Remove mercury and mercury-contaminated sludges from the sumps and fan rooms in Buildings 9201-4 and 9201-5.

- Remove mercury and mercury-contaminated sediments from the storm sewer system.

- Decommission and clean up the 81-10 area.

- Continue monitoring to determine the impact of the clean-up actions and where additional clean-up actions may be needed in the future.

Note: Plans were being formulated to dredge New Hope Pond.

These recommendations were accepted and work was well underway on this program when the water line broke, flooding the basement of building 9201-4 in June 1983.

Since the comprehensive drain line survey was completed in December 1982, subsequent monitoring, inspections, and other investigations have brought forth new information to develop plans to attempt to reduce the total quantity of mercury leaving the Y-12 Plant through East Fork Poplar Creek (EFPC).

- A plant water balance study was performed which indicated that about 85% or more of the water flowing from the Y-12 Plant into EFPC was once-through cooling water, purchased from the Oak Ridge Water Treatment Plant, and having no contact with process media. Some of this water was discharged into building drain systems and subsequently into the storm sewer system. In these travels, the clean water can and does get contaminated.

- Groundwater was not transporting any significant quantities of soluble mercury. What mercury was found was associated with particulates which do not travel in undisturbed groundwater systems.

- Mercury was found to be associated with particulate matter in Upper East Fork Poplar Creek which could be removed from the water by filtering with a 0.45 micron filter.

- Where mercury was spilled on natural soil or well-compacted fill covered with soil, it tends to remain in the top foot of the soil finely divided and adhering to the soil particles. Heavy rains producing surface runoff could allow some of this mercury to be transported to the storm sewer system.

- A process was developed that reduced mercury concentrations to about 0.002 mg/L (drinking water standards), but the process was costly (about $1.50 per gallon of water treated).
  Currently the following actions are recommended:

1. Remove residual sources of mercury and mercury-contaminated materials from the storm sewer system that are accessible without demolition or excavation.

  > By removing these sources of mercury contamination, they cannot escape into EFPC in the future. The most dramatic effect of removing these materials should be during storm flow conditions when deposits of these materials become resuspended, concentrations of mercury increase, and large pulses of mercury-contaminated sediments escape.

2. Remove residual sources of mercury and mercury-contaminated materials that are accessible without demolition from the buildings which contained the lithium isotope separation process equipment and pilot plants.

  > By removing these sources, they cannot escape into EFPC in the future.

3. Divert this once-through cooling water, and other clean waters, from contaminated areas into "clean conduits" to EFPC.

> Much of this clean water is becoming contaminated by the time it leaves the plant, particularly in 9204-4 and 9201-5. Many of the old building drain lines are contaminated with mercury. By rerouting this water through clean piping, the water can be kept clean, and the contaminated piping may be able to be isolated in place.

4. Rehabilitate the storm sewer system in the areas of Buildings 9204-4, 9201-4, and 9201-5.

> This will isolate mercury-contaminated materials which have exfiltrated through deteriorated pipes from the water flowing through the storm sewer system, decouple the storm sewer system from the groundwater, and will provide "clean conduits" for rerouted clean waters to enter EFPC.

5. Collect and treat residual sources of mercury-contaminated waters that cannot be eliminated.

> It is anticipated that not all of the mercury-contaminated waters can be eliminated.

6. Investigate the feasibility of lowering the water table around 9201-4.

> There is a spring that enters the sump in G fan room of that building and this water enters EFPC. The minimum flow has been measured at about 2 gpm (over one million gallons per year), and the water contains about 12 ppb mercury. The groundwater upgradient of this spring is clean. If there is a practical way to lower the water table and shut off the spring entering the building, this could save money on water treatment.

7. Investigate the feasibility of paving over all soils between First Street and Second Street, G Road and K Road.

> This would isolate mercury-contaminated soils from surface runoff during storm events as well as reduce the quantity of groundwater flowing through mercury-contaminated soils during storm events.

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APPENDIX A. COMPLETE RESULTS OF Y-12 DRAIN SURVEYS

Location	Date	Time	Flow (L/s)	pH	Cond (μS/cm)	Temp (°C)	Cl (mg/L)	Cl$_2$ (mg/L)	Hg (μg/L)	Hg Loading (g/d)
E8110/W	21DEC83	15:05	40.01	8.3	549	20.0	.	.	13.00	44.94
E8110N/W	21DEC83	13:15	81.22	7.8	280	20.0	.	.	2.30	16.14
E9404-14/2/N	24NOV83	10:20	1.18	7.6	277	17.4	.	.	150	15.26
E9404-14/2/W	23NOV83	10:15	0.07	7.8	471	16.5	.	.	76.00	0.44
E9720-12/NW	21DEC83	11:05	1.96	.8.6	531	13.2	.	.	5.00	0.85
E9720-12/W	21DEC83	11:00	11.74	7.1	1873	.14.6	.	.	1.50	1.52
E9803/E	24NOV83	13:40	2.24	7.6	294	15.6	.	.	1.00	0.19
E9811/N	28OCT82	10:40	54.60	7.1	263	25.0	8	0.00	2.80	13.21
E9811/N	28OCT82	16:00	54.60	7.2	247	26.0	8	0.06	2.90	13.68
E9811/N	28OCT82	19:10	54.60	10.7	1479	26.0	14	0.68	4.10	19.34
E9811/N	28OCT82	22:23	55.40	7.2	247	25.0	8	0.48	1.90	9.09
E9811/N	29OCT82	1:35	55.40	9.4	456	24.0	9	0.48	2.40	11.49
E9811/N	29OCT82	5:10	53.80	7.6	252	25.0	9	0.48	3.10	14.41
E9811/N	09DEC82	10:30	53.80	10.4	895	23.0	8	0.00	3.10	14.41
E9811/N	08JUN83	9:15	53.62	.	.	.	.	.	43.00	199.20
E9811/N	09JUN83	9:45	44.98	.	.	.	.	.	58.00	225.39
E9811/N	14DEC83	10:15	47.81	7.4	235	19.7	.	.	2.40	9.91
E9811/W	09DEC82	10:35	3.00	6.9	199	23.0	7	0.34	0.10	0.03
E9811/W	14UEC83	10:10	3.00	6.8	222	22.6	..	.	0.50	0.13
NE9201-4/N	10DEC82	8:42	43.00	7.2	249	20.0	8	0.17	0.10	0.37
NE9201-4/N	15DEC83	10:58	28.90	7.2	272	20.5	.	.	0.50	1.25
NE9201-5/N	07DEC83	11:00	0.89	7.9	266	44.8	.	.	0.50	0.04
NE9201-5/W	07DEC83	11:10	1.29	7.5	258	11.5	.	.	44.00	4.90
NE9201-5/W	07DEC83	11:15	1.29	7.6	.	10.4	.	.	32.00	3.57
NE9204-4/W	17NOV83	14:15	0.02	8.1	328	14.2	.	.	2.00	0.00
NE9404-14/E	24NOV83	11:10	0.29	7.5	231	16.8	.	.	5.00	0.12
NE9404-14/W	24NOV83	11:00	0.11	7.5	281	16.3	.	.	1.00	0.01
NE9720-5/N	08JUN83	10:50	4.30	.	.	.	.	.	21.00	7.80
NE9720-5/N	09JUN83	10:45	4.71	.	.	.	.	.	12.00	4.88
NE9720-5/N	17NOV83	9:00	35.77	8.1	317	16.3	.	.	1.00	3.09
NE9720-5/NW	09DEC82	12:15	42.00	7.1	297	16.0	9	0.00	16.00	58.06
NE9720-5/NW	08JUN83	10:50	35.22	.	.	.	.	.	20.00	60.86
NE9720-5/NW	09JUN83	10:45	31.83	.	.	.	.	.	11.00	30.25
NE9720-5/NW	17NOV83	8:45	38.51	7.7	344	13.4	.	.	8.00	26.62
NE9976/E	24NOV83	14:10	12.89	7.8	280	18.2	.	.	1.00	1.11
NHP INFLOW	28OCT82	8:55	372.00	6.8	335	19.0	9	0.05	4.40	141.42
NHP INFLOW	28OCT82	14:00	364.00	8.4	344	24.0	15	0.04	3.10	97.49
NHP INFLOW	28OCT82	18:05	379.00	6.9	375	23.0	24	0.02	3.90	127.71
NHP INFLOW	28OCT82	21:05	372.00	7.0	319	21.0	20	0.01	3.70	118.92
NHP INFLOW	29OCT82	3:40	357.00	7.4	313	20.0	9	0.08	4.40	135.72
NHP INFLOW	29OCT82	6:10	356.00	7.6	311	21.0	8	0.09	4.50	138.41
NHP INFLOW	09DEC82	8:32	402.00	7.6	516	17.0	74	0.32	3.60	125.04
NHP INFLOW	10DEC82	9:50	402.00	7.0	283	16.0	9	0.04	4.80	166.72
NHP INFLOW	28UEC82	12:20	1030.00	.	.	.	.	.	1.35	120.14
NHP INFLOW	28DEC82	15:35	637.00	.	.	.	.	.	1.95	107.32
NHP INFLOW	05APR83	15:00	.	.	.	.	.	.	11.00	.
NHP INFLOW	05JUN83	9:28	353.18	.	.	.	.	.	10.00	305.15
NHP INFLOW	05JUN83	19:21	341.07	.	.	.	.	.	11.00	324.15
NHP INFLOW	06JUN83	10:15	353.18	.	.	.	.	.	69.00	2105.5
NHP INFLOW	06JUN83	19:15	377.81	.	.	.	.	.	23.00	750.79
NHP INFLOW	07JUN83	9:58	341.07	.	.	.	.	.	20.00	589.37
NHP INFLOW	08JUN83	9:00	329.10	.	.	.	.	.	10.00	284.35
NHP INFLOW	08JUN83	19:25	341.07	.	.	.	.	.	1.00	29.47

Location	Date	Time	Flow (L/s)	pH	Cond (µS/cm)	Temp (°C)	Cl (mg/L)	Cl2 (mg/L)	Hg (µg/L)	Hg Loading (g/d)
NHP INFLOW	09JUN83	9:00	329.10	.	.	.	.	.	12.00	341.21
NHP INFLOW	09JUN83	19:00	341.07	.	.	.	.	.	21.00	618.84
NHP INFLOW	28OCT92	0:10	364.00	7.2	285	21.0	9	0.06	4.30	135.23
NHP OUTFLOW	28OCT82	8:20	372.00	6.8	355	16.0	16	0.00	1.80	57.85
NHP OUTFLOW	28OCT82	13:44	364.00	7.5	311	21.0	14	0.00	2.50	78.62
NHP OUTFLOW	28OCT82	17:58	379.00	7.8	341	22.0	14	0.00	2.70	88.41
NHP OUTFLOW	28OCT82	20:55	372.00	7.4	365	21.0	21	0.00	2.10	67.50
NHP OUTFLOW	28OCT82	24:00	364.00	7.1	366	20.0	23	0.00	1.70	53.46
NHP OUTFLOW	29OCT82	3:35	357.00	7.3	332	19.0	17	0.00	2.00	61.69
NHP OUTFLOW	29OCT82	6:00	357.00	7.3	320	18.0	14	0.00	1.90	58.61
NHP OUTFLOW	09DEC82	8:47	402.00	7.1	295	14.0	12	0.19	1.20	41.68
NHP OUTFLOW	10DEC82	9:55	402.00	7.1	312	14.0	13	0.00	1.20	41.68
NHP OUTFLOW	28DEC82	12:20	1030.00	.	.	.	.	.	1.00	88.99
NHP OUTFLOW	28DEC82	15:35	637.00	.	.	.	.	.	0.90	49.53
NHP OUTFLOW	05APR83	15:00	.	.	.	.	.	.	9.80	.
NHP OUTFLOW	05JUN83	9:37	353.18	.	.	.	.	.	4.00	122.06
NHP OUTFLOW	05JUN83	19:29	341.07	.	.	.	.	.	4.00	117.87
NHP OUTFLOW	06JUN83	10:15	353.18	.	.	.	.	.	4.00	122.06
NHP OUTFLOW	06JUN83	19:05	377.81	.	.	.	.	.	5.00	163.22
NHP OUTFLOW	07JUN83	9:58	341.07	.	.	.	.	.	3.00	88.41
NHP OUTFLOW	08JUN83	9:00	329.10	.	.	.	.	.	3.00	85.30
NHP OUTFLOW	08JUN83	19:30	341.07	.	.	.	.	.	14.00	412.56
NHP OUTFLOW	09JUN83	9:00	329.10	.	.	.	.	.	4.00	113.74
NHP OUTFLOW	09JUN83	19:10	341.07	.	.	.	.	.	12.00	353.62
NW9201-4/E	01DEC83	.	.	7.6	240	12.6	.	.	40.00	.
NW9401-3/E	01DEC83	10:10	10.13	7.8	267	20.0	.	.	0.50	0.44
NW9401-3/N	01DEC83	10:05	15.33	7.8	286	22.0	.	.	23.00	30.47
NW9401-3/W	01DEC83	10:30	0.00	2.3	5650	13.5	.	.	4.00	0.00
NW9404-17/NE	01DEC83	.	.	7.9	263	18.2	.	.	170	.
NW9720-3/NW	15DEC83	13:00	3.51	7.4	330	10.9	.	.	8.00	2.43
NW9720-5/NE	09DEC82	15:50	3.90	7.5	299	16.0	9	0.00	14.00	4.72
NW9720-5/NE	21DEC83	9:45	2.28	7.7	329	11.5	.	.	5.50	1.08
NW9720-5/W	28OCT82	13:15	9.60	7.0	819	21.0	5	0.00	1.20	1.00
NW9720-5/W	28OCT82	16:30	9.60	6.8	834	21.0	8	0.00	1.10	0.91
NW9720-5/W	28OCT82	19:45	9.60	6.8	849	20.0	8	0.00	1.30	1.08
NW9720-5/W	28OCT82	22:47	16.80	6.9	815	21.0	8	0.00	1.40	2.03
NW9720-5/W	29OCT82	2:10	13.20	6.9	856	20.0	8	0.00	1.30	1.48
NW9720-5/W	29OCT82	5:40	11.20	6.9	851	20.0	8	0.00	1.20	1.16
NW9720-5/W	09DEC82	15:45	29.20	6.3	748	16.0	7	0.00	2.00	5.05
NW9720-5/W	21DEC83	9:46	6.28	7.1	1684	14.5	.	.	1.50	0.81
N9201-4/N	15DEC83	14:30	0.00	7.5	348	11.3	.	.	3.50	0.00
N9201-4/W	15DEC83	14:35	0.00	7.5	280	11.7	.	.	2.40	0.00
N9201-5/1N	07DEC83	13:47	1.92	7.5	257	10.7	.	.	150	24.94
N9201-5/3W	07DEC83	12:52	1.78	7.6	259	10.0	.	.	31.00	4.77
N9204-4/M	17NOV83	13:15	0.00	8.1	114	10.7	.	.	0.50	0.00
N9720-3	10DEC82	9:25	0.55	7.2	401	15.0	25	0.07	4.70	0.22
N9720-3	15DEC83	11:10	4.71	6.9	325	10.8	.	.	3.00	1.22
N9723-19/N	17NOV83	15:00	0.02	7.5	183	19.8	.	.	24.00	0.03
N9727-3/E	15DEC83	14:55	.	9.8	546	13.5	.	.	5.60	.
SE9103	08DEC83	9:30	0.01	7.8	321	11.9	.	.	1.50	0.00
SE9201-4/E	14DEC83	11:25	1.17	7.5	235	21.4	.	.	0.50	0.05
SE9201-4/N	14DEC83	11:20	109.57	7.4	277	21.2	.	.	7.80	73.84
SE9201-5/S	01DEC83	.	1.50	8.0	265	18.3	.	.	15.00	1.94

Location	Date	Time	Flow (L/s)	pH	Cond (µS/cm)	Temp (°C)	Cl (mg/L)	Cl$_2$ (mg/L)	Hg (µg/L)	Hg Loading (g/d)
SE9201-5/W	01DEC83	.	6.4129	8.20	306	19.0	.	.	37.00	20.50
SE9204-4/N	17NOV83	10:10	0.0066	7.90	317	16.5	.	.	0.50	0.00
SE9204-4/W	17NOV83	10:00	24.0358	7.80	321	14.2	.	.	29.00	60.22
SE9204-4/W	08AUG84	10:40	25.0000	7.92	285	.	.	.	11.00	23.76
SE9204-4/W	09AUG84	9:30	19.0000	7.91	306	.	.	.	.	.
SE9404-12/N	08DEC83	14:40	0.0050	7.70	486	16.6	.	.	610	0.26
SE9404-12/W	08DEC83	14:45	0.0080	8.20	390	15.3	.	.	14.00	0.01
SE9720-3/E	15DEC83	10:05	1.9000	7.20	681	14.5	.	.	2.90	0.48
SE9720-3/N	15DEC83	10:00	84.1689	7.60	272	19.5	.	.	0.50	3.64
SE9720-5/N	09DEC82	12:55	66.0000	7.30	297	16.0	8	0.00	.	.
SE9720-5/W	09DEC82	12:55	30.0000	6.80	643	15.0	7	0.00	3.80	9.85
SE9720-5/W	08JUN83	10:37	15.4366	.	.	.	.	.	1.00	1.33
SE9720-5/W	09JUN83	10:30	18.5203	.	.	.	.	.	1.00	1.60
SE9723-18/N	15DEC83	13:45	2.9831	7.10	260	10.3	.	.	11.00	2.84
SE9723-18/W	15DEC83	13:50	1.2598	8.50	374	11.4	.	.	1.80	0.20
SE9723-19/N	07DEC83	14:21	0.0250	7.20	.	38.4	.	.	41.00	0.09
SE9723-21/NE	07DEC83	15:40	0.0400	8.00	272	22.7	.	.	5.70	0.02
SE9723-21/NW	07DEC83	15:37	.	8.10	230	56.6	.	.	0.50	.
SW9201-4/E	09DEC82	15:30	0.0500	6.90	27	23.0	2	0.00	87.00	0.38
SW9201-4/E	08JUN83	12:30	0.0300	.	.	.	.	.	530	1.37
SW9201-4/E	09JUN83	12:55	0.0300	.	.	.	.	.	67.00	0.17
SW9201-4/E	01DEC83	11:32	0.3473	7.40	25	20.4	.	.	32.00	0.96
SW9201-4/N	09DEC82	15:17	6.0300	7.60	290	22.0	13	0.55	28.00	14.59
SW9201-4/N	08JUN83	12:30	5.3536	.	.	.	.	.	160	74.01
SW9201-4/N	08JUN83	12:30	6.8339	.	.	.	.	.	7.00	4.13
SW9201-4/N	09JUN83	12:55	5.3536	.	.	.	.	.	150	69.38
SW9201-4/N	09JUN83	12:55	5.3838	.	.	.	.	.	8.00	3.72
SW9201-4/N	01DEC83	11:16	5.7477	7.90	343	· 21.6	.	.	36.00	17.88
SW9201-4/NE	09DEC82	15:26	0.0300	7.30	365	19.0	11	0.00	980	2.54
SW9201-4/NE	08JUN83	12:30	0.0300	.	.	.	.	.	940	2.44
SW9201-4/NE	09JUN83	12:55	0.0300	.	.	.	.	.	980	2.54
SW9201-4/NE	01DEC83	11:33	0.0867	7.60	347	18.1	.	.	440	3.30
SW9201-4/W	09DEC82	15:15	2.4800	7.50	266	21.0	8	0.58	2.60	0.56
SW9201-4/W	01DEC83	11:20	6.7326	8.10	304	19.5	.	.	3.60	2.09
SW9204-2/N	15DEC83	9:25	59.8156	7.60	281	19.2	.	.	0.60	3.10
SW9204-2/W	09DEC82	14:55	0.6700	7.40	360	21.0	16	0.21	79.00	4.57
SW9204-2/W	15DEC83	9:30	0.8056	7.70	297	16.8	.	.	71.00	4.94
SW9204-3	09DEC82	10:09	1.2000	6.90	238	16.0	7	0.82	0.70	0.07
SW9204-4	21DEC83	11:40	0.8800	7.80	546	13.7	.	.	4.20	0.32
SW9204-4/N	09DEC82	16:50	0.0300	7.30	366	19.0	.	0.12	2.10	0.01
SW9204-4/NE	09DEC82	16:40	.	7.10	237	16.0	.	.	4.80	.
SW9204-4/2N	21DEC83	13:00	0.2000	7.90	441	18.8	.	.	0.70	0.01
SW9204-4/2NE	21DEC83	13:10	0.5380	7.60	270	15.2	.	.	2.80	0.13
SW9204-4/3	21DEC83	13:32	2.8000	7.90	276	23.3	.	.	0.50	0.12
SW9401-3/N	29OCT82	12:40	22.0000	6.70	272	27.0	.	0.00	15.00	28.51
SW9401-3/N	09DEC82	14:15	22.0000	6.30	534	23.0	9	0.00	14.00	26.61
SW9404-20/N	17NOV83	9:40	35.0541	7.70	366	13.9	.	.	5.00	15.14
SW9404-20/N	08AUG84	9:45	46.0000	7.93	300	.	.	.	3.80	15.10
SW9404-20/N	09AUG84	9:10	43.0000	7.75	298	.	.	.	.	.
SW9723-16/N	07DEC83	10:22	0.0400	7.60	329	15.8	.	.	0.60	0.00
SW9727-4/N	28OCT82	13:00	3.9000	7.40	847	27.0	150	0.02	61.00	20.55
SW9727-4/N	28OCT82	15:30	29.9000	2.40	4561	21.0	300	0.00	2.10	5.43
SW9727-4/N	28OCT82	19:25	2.2000	6.70	503	28.0	56	0.07	14.00	2.66

Location	Date	Time	Flow (L/s)	pH	Cond (µS/cm)	Temp (°C)	Cl (mg/L)	Cl$_2$ (mg/L)	Hg (µg/L)	Hg Loading (g/d)
W9727-4/N	28OCT82	22:35	3.0000	7.40	505	27.0	43	0.06	7.30	1.89
W9727-4/N	29OCT82	1:52	2.8000	7.50	512	25.0	37	0.06	8.70	2.10
W9727-4/N	29OCT82	5:22	3.2000	7.60	393	25.0	22	0.07	9.50	2.63
W9727-4/N	09DEC82	14:30	13.0000	7.00	449	23.0	26	0.22	3.10	3.48
W9727-4/N	08JUN83	13:00	4.5851	.	.	.	.	.	8.00	3.17
W9727-4/N	09JUN83	11:20	7.0116	.	.	.	.	.	10.00	6.06
W9727-4/N	08DEC83	10:20	18.1000	10.70	452	11.0	.	.	1.60	2.50
W9727-4/N	08DEC83	10:30	55.1000	10.80	402	10.8	.	.	3.60	17.14
W9727-4/N	08DEC83	10:45	38.9000	1.10	86000	12.2	.	.	2.80	9.41
W9727-4/W	08DEC83	10:55	0.0010	.	.	.	.	.	0.70	0.00
SW9803/N	24NOV83	12:45	2.9650	7.80	299	16.0	.	.	3.00	0.77
SW9803/W	24NOV83	12:40	0.5600	8.50	383	20.4	.	.	1.00	0.05
SW9804/N	08DEC83	13:00	1.3700	9.30	237	19.4	.	.	18.00	2.13
SW9976/N	09DEC82	16:14	5.9000	7.50	245	18.0	8	1.00	1.20	0.61
SW9976/N	17NOV83	9:15	7.3475	7.70	283	17.3	.	.	7.00	4.44
SW9976/NW	09DEC82	16:20	48.6000	7.50	299	15.0	8	0.00	13.00	54.59
SW9976/NW	17NOV83	9:20	38.3385	7.60	374	14.4	.	.	9.00	29.81
S9103/N	17NOV83	13:45	0.0125	7.80	249	14.3	.	.	7.00	0.01
S9103/N	08DEC83	9:15	0.0125	7.50	213	12.2	.	.	10.00	0.01
S9201-4/N	14DEC83	9:24	0.6726	7.20	682	18.8	.	.	2.20	0.13
S9201-5/E	10DEC82	9:05	5.7000	7.90	371	20.0	13	0.02	0.30	0.15
S9201-5/E	24NOV83	9:35	4.5299	7.90	334	16.8	.	.	1.00	0.39
S9201-5/N	10DEC82	9:00	3.0000	6.80	134	19.0	2	0.08	56.00	14.52
S9201-5/N	24NOV83	9:30	1.7500	7.40	283	17.4	.	.	16.00	2.42
S9201-5/N	24NOV83	9:45	7.0000	7.70	483	18.9	.	.	75.00	45.36
S9204-4/N	17NOV83	10:30	38.6969	7.70	281	15.9	.	.	19.00	63.52
S9204-4/N	08AUG84	13:10	23.0000	7.96	235	.	.	.	3.90	7.75
S9204-4/N	09AUG84	10:05	25.0000	7.97	237	.	.	.	8.00	17.28
S9204-4/N	03OCT84	16:15	.	.	.	.	.	.	6.40	.
S9204-4/N	03OCT84	16:15	.	.	.	.	.	.	7.50	.
S9204-4/N	03OCT84	18:15	.	.	.	.	.	.	5.20	.
S9204-4/N	03OCT84	20:15	.	.	.	.	.	.	10.70	.
S9204-4/N	03OCT84	22:15	.	.	.	.	.	.	8.80	.
S9204-4/N	04OCT84	0:15	.	.	.	.	.	.	11.60	.
S9204-4/N	04OCT84	2:15	.	.	.	.	.	.	11.80	.
S9204-4/N	04OCT84	4:15	.	.	.	.	.	.	11.60	.
S9204-4/N	04OCT84	6:15	.	.	.	.	.	.	12.30	.
S9204-4/N	04OCT84	8:15	.	.	.	.	.	.	6.40	.
S9204-4/N	04OCT84	10:15	.	.	.	.	.	.	9.10	.
S9204-4/N	04OCT84	12:15	.	.	.	.	.	.	7.10	.
S9204-4/N	04OCT84	13:30	.	.	.	.	.	.	6.10	.
S9204-4/N	04OCT84	15:30	.	.	.	.	.	.	5.00	.
S9204-4/N	04OCT84	17:30	.	.	.	.	.	.	2.50	.
S9204-4/N	04OCT84	19:30	.	.	.	.	.	.	9.50	.
S9204-4/N	04OCT84	21:30	.	.	.	.	.	.	6.30	.
S9204-4/N	04OCT84	23:30	.	.	.	.	.	.	12.30	.
S9204-4/N	05OCT84	1:30	.	.	.	.	.	.	15.00	.
S9204-4/N	05OCT84	3:30	.	.	.	.	.	.	16.10	.
S9204-4/N	05OCT84	5:30	.	.	.	.	.	.	15.30	.
S9204-4/N	05OCT84	7:30	.	.	.	.	.	.	16.50	.
S9204-4/N	05OCT84	9:30	.	.	.	.	.	.	14.50	.
S9204-4/N	05OCT84	11:30	.	.	.	.	.	.	6.50	.
S9204-4/S	17NOV83	8:45	10.8103	7.90	329	13.9	.	.	2.00	1.87

Location	Date	Time	Flow (L/s)	pH	Cond (µS/cm)	Temp (°C)	Cl (mg/L)	Cl$_2$ (mg/L)	Hg (µg/L)	Hg Loading (g/d)
1719S	05APR83	15:00	.	.	.	.	.	.	4.10	.
1719S	05JUN83	9:07	43.3290	.	.	.	.	.	10.00	37.44
1719S	06JUN83	9:00	80.9608	.	.	.	.	.	22.00	153.89
1719S	06JUN83	19:30	68.5485	.	.	.	.	.	7.00	41.46
1719S	07JUN83	9:20	38.8007	.	.	.	.	.	16.00	53.64
1719S	08JUN83	9:00	28.6531	.	.	.	.	.	21.00	51.99
1719S	08JUN83	19:00	31.8596	.	.	.	.	.	17.00	46.80
1719S	09JUN83	9:15	31.8596	.	.	.	.	.	15.00	41.29
1719S	09JUN83	19:30	36.4052	.	.	.	.	.	43.00	135.25
295.5	10DEC82	13:55	0.0100	7.0	238	14	6	1.10	0.10	0.00
298	10DEC82	13:45	1.7600	7.5	225	21	6	0.00	1.00	0.15
667	28OCT82	9:20	18.9000	7.2	261	22	9	1.10	0.52	0.85
667	28OCT82	14:15	20.3000	7.6	272	28	15	3.70	0.91	1.60
667	28OCT82	18:22	17.6000	7.5	267	24	9	0.95	0.24	0.36
667	28OCT82	21:22	18.2000	7.6	252	24	7	0.32	0.18	0.28
667	29OCT82	0:25	17.6000	7.6	262	23	7	0.25	0.15	0.23
667	29OCT82	4:00	17.6000	7.6	248	22	7	0.48	0.16	0.24
667	10DEC82	13:37	28.2000	8.0	268	25	15	1.00	0.20	0.49
667	10DEC82	14:10	30.9000	9.5	823	30	31	0.10	0.40	1.07
763	10DEC82	13:30	5.1000	7.4	248	25	7	0.74	0.50	0.22
851	10DEC82	13:24	0.0300	7.8	217	18	7	0.74	0.10	0.00
909.4	10DEC82	13:17	14.0000	7.4	248	19	7	0.98	0.80	0.97
909.4	06DEC83	13:40	5.7399	.	.	.	.	.	2.50	1.24
910.4	28OCT82	9:40	21.3000	6.9	264	20	6	1.20	0.13	0.24
910.4	28OCT82	14:25	21.3000	7.1	260	23	7	1.15	0.10	0.18
910.4	28OCT82	18:25	20.0000	7.1	157	33	7	1.35	0.08	0.14
910.4	28OCT82	21:34	21.9000	7.2	253	21	6	1.20	0.09	0.17
910.4	29OCT82	0:40	23.2000	7.2	254	21	7	1.18	0.05	0.10
910.4	29OCT82	4:20	26.6000	7.0	258	20	7	1.25	0.07	0.16
910.4	10DEC82	13:15	19.9000	7.3	243	16	7	1.10	0.30	0.52
910.4	06DEC83	13:50	14.1206	.	.	.	.	.	0.50	0.61
915	28OCT82	9:55	4.2000	7.3	298	18	7	0.35	13.00	4.72
915	28OCT82	14:35	2.3000	7.5	231	22	6	1.00	41.00	8.15
915	28OCT82	18:45	2.1000	7.3	273	21	8	3.40	22.00	3.99
915	28OCT82	21:40	2.6000	7.5	227	20	6	0.92	32.00	7.19
915	29OCT82	0:45	2.6000	7.6	235	20	6	0.85	37.00	8.31
915	29OCT82	4:30	2.6000	7.4	226	19	6	1.00	32.00	7.19
915	10DEC82	13:00	3.7000	7.4	233	19	7	1.10	27.00	8.63
915	08JUN83	13:30	2.8670	.	.	.	.	.	18.00	4.46
915	09JUN83	13:40	10.1923	.	.	.	.	.	17.00	14.97
915	06DEC83	14:00	4.6116	.	.	.	.	.	21.00	8.37
935.6	10DEC82	12:55	13.0000	6.8	412	15	5	0.01	2.20	2.47
980.5	10DEC82	12:45	11.4000	7.2	242	18	8	1.10	2.30	2.27